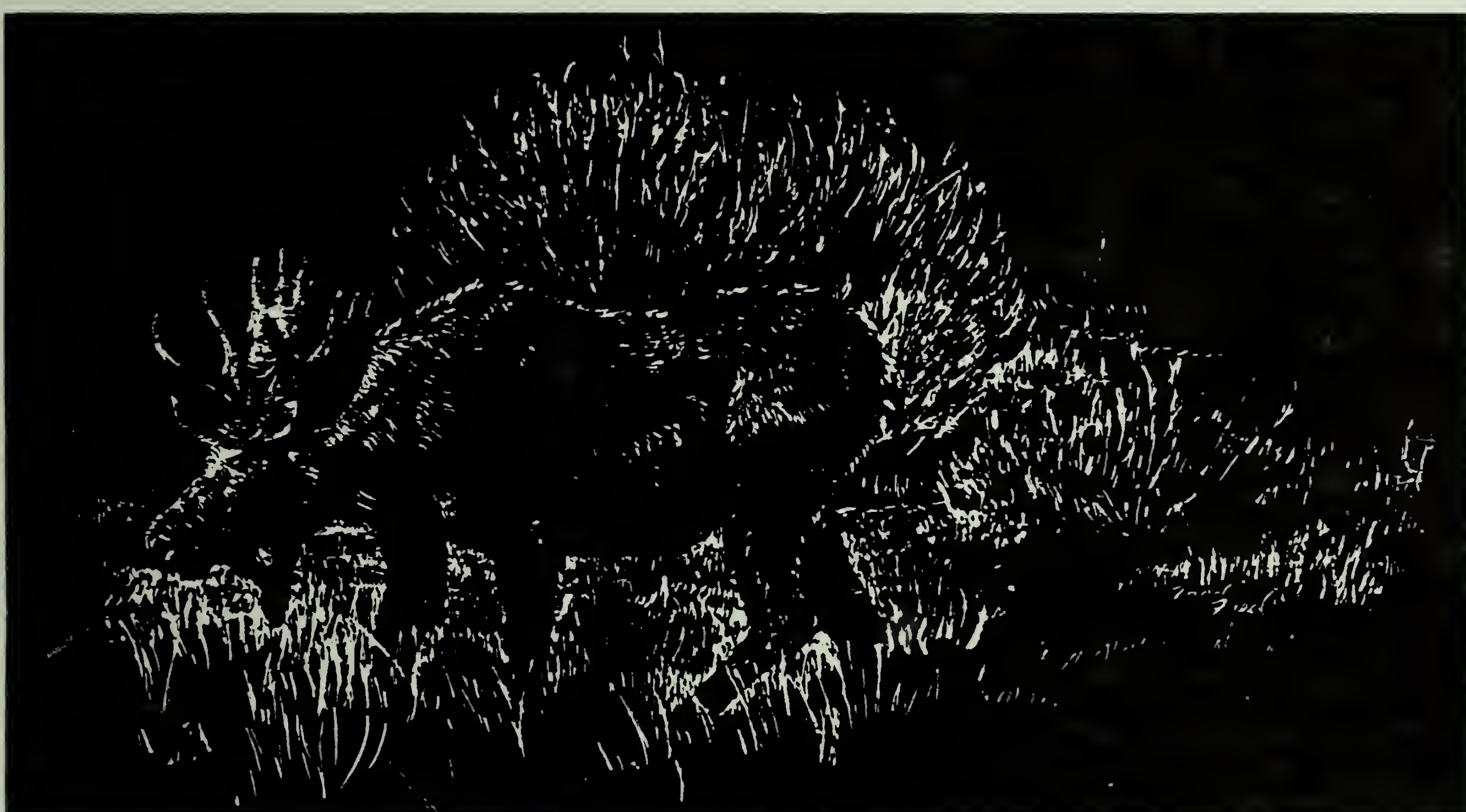
GRAZING INFLUENCES ON YELLOWSTONE'S NORTHERN RANGE

II

Research Summaries August 15, 1990



Compiled by

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GRAZING INFLUENCES ON YELLOWSTONE'S NORTHERN RANGE

II

TABLE OF CONTENTS

Page

INTRODUCTION

This is the second annual report of project summaries on the ecology of Yellowstone's northern ungulate winter range. It is intended primarily as an interim briefing statement for the park Superintendent until such a time as final reports and publications become available. Copies of the first report, printed in July 1989, are still available from the Research Division, P.O. Box 168, Yellowstone National Park, Wyoming 82190. In addition, the highlights of both the 1989 and 1990 reports have been condensed into a companion report entitled "A Digest of Research into Grazing Influences by Native Ungulates on Yellowstone's Northern Winter Range." It is also available from the Research Division.

This report summarizes studies funded through a large National Park Service (NPS) research initiative of the Natural Resources Preservation Program, 1985-1988. The report also includes northern range research funded by other NPS sources, especially postfire and wolf study funds, as well as studies partially or wholly funded by sources outside the NPS.

This report is the second response to the October 1987 Congressional Directive to the National Park Service to: "start a study on Yellowstone to see whether there is evidence of overgrazing."

TITLE: Effects of the 1988 fires on the northern range: 1989 forage productivity, winter elk habitat use, and snow relations

AUTHORS: Jack E. Norland and Francis J. Singer, Yellowstone National Park

PUBLICATION REPORT STATUS:
1. Annual reports.
2. Publication in Journal Wildlife Management, Summer 1991.

OTHER PROJECTED PUBLICATIONS:
Data will contribute to nutritionally-based model of elk carrying capacity slated for J. Applied Ecology.

PROJECTED PUBLICATION DATE: Summer 1991.

INTRODUCTION:

The fires of 1988 burned extensive portions of the winter range on the northern range. Fires in previous studies (Christensen et al 1989) have shown that fires increase forage production and change ungulate habitat use patterns to where more use is in the burned areas. The fires in Yellowstone are hypothesized to increase forage production in all major habitats resulting in more elk use in the burned areas. With the increase in production we also hypothesized an increase in forage quality and an increase in elk use of the burned areas. Snow relations in the burned areas may mediate the change in use of burned areas by elk. Snow relations are hypothesized not to change in forested areas only influenced by surface burns. In canopy burned areas greater depth and harder snow structure due to the lack of tree canopy could result in a decrease in elk use. In sagebrush areas the snow relations may result in less use because sagebrush is thought to facilitate elk foraging in the snow.

METHODS:

1. Forage production under 40 cm was measured in both Douglas fir habitats and sagebrush habitats. The Douglas fir habitat had production stratified by soil heating properties, those soils which were heated to a depth of 5 cm were classified as moderate and those which only had the surface organic material charred classified as light. In each habitat four sites were chosen where similar conditions occurred in the burned and unburned areas. At each site 15 .5 meter sq. plots were chosen along a 60 meter transect. Transect ends were marked so the exact plots can be resampled in the future. At each plot the production of each species was measured with the canopy intercept method of Frank and McNaughton (1990). The sagebrush production was measured in September and early October of 1989, and the Douglas fir from early October

to early November 1989. Production was analyzed utilizing a blocked ANOVA design and only forage classes were examined.

2. Habitat use by elk was estimated for sagebrush and Douglas Fir habitats. Habitat use was indexed by estimating the density of feeding craters in habitats in burned and unburned portions. Ten pairs of burned to unburned comparisons were chosen in each habitat. In addition four transects were placed in a canopy burned Douglas Fir habitat to compare against similar surfaced burned only Douglas Fir habitats. Belt transects 4 meters in width and approximately .75 km long were randomly placed in each site. Transects estimated approximately 5% of the total area of the site. Transects were run in December and January, for early winter estimate of use, and in February for late winter estimate. Data was analyzed in a blocked ANOVA design where each paired comparison was a block.

3. Snow relations were measured in both sagebrush and Douglas Fir habitats. Snow depths and densities were measured with the standard SCS snow sampler tube. Within each habitat four sites were chosen with burned and unburned areas which had similar conditions. At each site 10 feeding craters were randomly chosen and the depth and density of snow was measured. In addition 10 sites were measured in a canopy burned Douglas Fir area to be compared with the other Douglas fir sites. To see how different snow depths and density was from idealized snow depths without any influence from wind, tree canopy, or other disturbance snow courses following the SCS guidelines for site selection of these were followed. The comparison of these with the depths will show how different the feeding sites are from the idealized depths and densities. Data was collected in January 1990 for early winter and late February and March for late winter. Depths and densities were analyzed using a blocked ANOVA design. Multiple comparisons used Tukeys HSD.

4. All significant differences were at the $P<.05$ level.

SUMMARY OF PROGRESS AND FINDINGS:

1. Forage production the first growing season after the fires decreased about 23% on the Northern range in the sagebrush habitats (Table 1). The decrease was attributed to small patches in the burned sagebrush areas which had plants killed by moderate soil heating.

2. Forage production in the Douglas Fir forest was decreased in those areas that had moderate soil heating, but was not different on those areas only lightly heated. The drop in production in the moderately heated soil was due to the

plants being killed by the fire. The lightly heated soil had few plants killed by the fire. In the future species composition will be compared between treatments looking at differences and changes as both treatments evolve.

3. The habitat use of burned areas by elk was not significantly different from the use of unburned areas for both sagebrush and Douglas fir habitats. Even the canopy burned area in the Douglas fir did not differ in the amount of use.

4. Depths of snow at feeding sites were significantly different between burned and unburned sites in both sagebrush and Douglas fir habitats. Canopy burned Douglas fir habitats had significantly deeper snow than the burned and unburned treatments. Snow course snow depths were significantly deeper than all of the treatments in both habitats. Greater snow course depths were not unexpected since elk will select lower snow cover when available. Deeper snows in canopy burned sites was expected since previous studies (personnel communication Phil Farnes, SCS) had found that the removal of tree canopy results in higher snow depths.

5. Snow densities were significantly different for several treatments in both habitats. The interpretation of the densities has not been worked out. Further work will be conducted on how snow densities influence on elk foraging behavior.

6. There was no change in in the habitat use of the elk due to the changes brought about by the fires. Future changes in the various resource parameters measured may eventually alter elk foraging behavior, but the changes in resource parameters the first year post fire did not alter elk habitat use.

Several other aspects are being studied which will have a bearing on the interpretation of these results, these being: 1. forage quality in both habitats, 2. winter diets of elk. In the future these will be incorporated into the interpretation of these data.

Literature Cited:

Christensen, N.L. et al. 1989. Ecological consequences of the 1988 fires in the Greater Yellowstone area. National Park Service, Yellowstone National Park, WY.

Frank, D.A. and S.J. McNaughton. 1990. Aboveground biomass estimation with the canopy intercept method: a plant growth form caveat. Oikis: in press.

Table 1. Mean forage production, grams/meter sq., on the northern range (SE in parenthesis).

Forage	Sagebrush Burned	Unburned
Graminoid	84.5 (9.2)A	117.5 (9.4)B
Forb	15.4 (1.7)A	11.5 (1.3)B
Total	99.9 (9.3)A	129.1 (9) B

Forage	Douglas Fir Moderate Burned	Light Burned	Unburned
Graminoid	1.5 (0.5)A	52.4 (6.6)B	63.3 (5.5)B
Forbs	0.9 (0.4)A	5.3 (0.8)B	6.1 (0.8)B
Shrubs	0.7 (0.4)A	7.2 (1.1)B	9.4 (1.7)B
Total	3.1 (0.9)A	64.9 (7.2)B	78.8 (5.7)B

means not followed by a common letter were significantly different $p<0.05$

Table 2. Mean snow depths in inches and mean percent densities of snow for early and late winter (SE in parentheses).

	Lodgepole Forest Burned	Unburned	Snow Course	Canopy Burned
Depth-Early	10.5(0.4)C	9.3(0.4)C	17.3(0.2)A	13.3(0.6)B
Depth-Late	14.7(0.5)C	14.6(0.4)C	24.6(0.4)A	20.7(0.6)B
Density-Early	16.3(0.5)AB	14.6(0.6)A	16.3(0.4)B	15.4(0.6)AB
Density-Late	19.9(0.7)AB	19.3(0.6)A	21.8(0.3)B	20.9(0.3)AB

	Sagebrush Burned	Unburned	Snow Course
Depth-Early	14.3(0.4)A	14.5(0.3)A	17.3(0.2)B
Depth-Late	17.7(0.6)A	17.2(0.4)A	24.6(0.4)B
Density-Early	16.7(0.5)A	17.7(0.5)A	16.4(0.4)A
Density-Late	22.6(0.5)B	20.6(0.5)A	21.8(0.3)AB

means not followed by a common letter were significantly different $P<0.05$.

PROGRESS REPORT - COOPERATIVE MOOSE PROJECT

TITLE

Ecology of moose on the Northern Winter Range of Yellowstone National Park and the Gallatin National Forest.

AUTHORS

Daniel Tyers for: Frank Singer, Tom Lemke, Dr. Lynn Irby.

AFFILIATION

U.S. Forest Service; National Park Service; Montana Department of Fish, Wildlife and Parks; and Montana State University. (The Safari Club International - Montana Chapter is an additional cooperator but is not an author of this report.)

PUBLICATION REPORT STATUS

Project still in progress. Completion date for fieldwork is fall 1990. Data analyses and report writing are scheduled for winter 1990-1991.

A dissertation will also result from the project.

OTHER PROJECTED PUBLICATIONS

It is anticipated that a variety of papers will be written cooperatively by the agencies involved. This will occur where this project overlaps with other projects and where certain specific agency interests need to be expressed. These areas have yet to be identified.

PROJECTED PUBLICATION DATE FOR WORK IN PREPARATION

1991 or 1992.

DATE OF PROGRESS REPORT

July 1990.

SUMMARY OF OBJECTIVES

1. Determine the effect of 1988 fires on the Shiras moose on the Northern Winter Range of Yellowstone National Park and the Gallatin National Forest.

2. Describe the winter ecology of the Shiras moose on the Northern Winter Range.

3. Provide management recommendations to the participating agencies relevant to such issues as hunting quotas and vegetation manipulation (i.e. silvicultural practices and prescribed burning).

4. Provide baseline data on population size and trends, and determine the validity of different census techniques.

5. Obtain information on the relationship between moose and the willow communities on the Northern Winter Range.

SUMMARY OF MOST SIGNIFICANT FINDINGS

1. Effect of the 1988 fires: Two years of data were collected on moose habitat and dietary preferences, home range size, and population dynamics before the fires of 1988. The same methodology used before the fires was continued for 2 years after the fire. A comparison of pre- and post-fire data for moose in areas that burned indicates important changes in diet, home range size, cow/calf ratios, and distribution.

The moose used several strategies for foraging in areas where their habitat was changed by the fires. After the fires, lodgepole pine and, to a lesser degree, willow increased in the diet of moose in burned drainages. The first year after the fire, the burned twigs of lodgepole were prominent in the diet of moose in one of the study units (Slough Creek) that burned extensively. In some cases, moose moved to a higher elevation to get above the perimeter of burned areas to forage. This often resulted in the moose foraging in snow depths in excess of previous years' averages. In general, moose demonstrated a pronounced avoidance of burned areas during the winter for the 2 years following the fires of 1988.

2. Winter ecology: Collecting data for 4 years has brought a good understanding of moose habitat and dietary preferences from four different study units within the study area. This is for the time frame of November to April. The main browse species are: subalpine fir, willow, gooseberry, lodgepole pine, and buffalo berry. The relative proportions of these browse species in the diet of the moose vary significantly from month to month and from study unit to study unit through the winter. However, there is a lot of consistency from year to year. The distance traveled for the equivalent number of "bites" in each feeding effort also varies a great deal by month, study unit, and cover type. In areas that have burned or have more wintering elk, the moose tend to travel further when browsing. Also, there is a strong relationship between moose and late successional stage lodgepole and spruce-fir forests. They will spend much of the winter in these cover types.

3. Management recommendations: No decisions have been made based on the data collected through this project as to whether the hunting quotas for moose are commensurate with the population size. However, the State expects to use information from this project to assist in making these decisions and to monitor the appropriateness of the harvest levels.

The best moose winter range appears to be between 7000-8000 feet, in late successional lodgepole and spruce-fir forests, and where snow depths average between 70-110 cm. In addition, in preferred sites the understory of subalpine fir and gooseberry appears to be comparatively very high. Timber harvest in these areas has the biggest impact on moose. A disparity in snow accumulation and consistency between older forests and clearcuts make clearcuts less desirable to moose. Harvest units have greater snow depths and more heavily crusted snow conditions than adjacent uncut forests. These factors make the retention and location of intact forests important as travel corridors. Timber harvest has enhanced moose habitat in some locations. This has occurred where the forest canopy has been opened next to decadent willow communities allowing them to increase, and where selective cutting has partially opened the forest canopy allowing an increase in understory shrub production while still maintaining hiding and thermal cover.

4. Population size and trend/census techniques: A survey was conducted from horseback for 4 years in the 1940s and then repeated for 5 years in the 1980s to classify the moose population. It will be repeated for 4 more years. It seems to indicate a decline in the number of moose seen per day from the 1940s to the 1980s and a decline in the number of calves per cows after the fires of 1988.

Attempts to count moose from fixed-wing aircraft have identifed two brief and predictable windows of observability for seeing moose. These occur during about the first of December and the end of April when the moose congregate in several large willow communities. The reason why the moose congregate at these specific times is not entirely known. Efforts to count moose at all other times of the year are very unproductive.

A sightability model is still in the developmental stages.

5. Relationship between moose and willow communities: Moose winter range in the study area extends from about 6800 feet to 8800 feet. Willow communities are found at all elevations within this zone. Elk are also found in the study area but usually winter lower in elevation than the moose, although there is some overlap. Snow depth and consistency impact when both elk and moose use willow communities for browsing. Track transects reveal that snow precludes the availablity of willow communites located at the highest end of moose winter range from late December to early June. Very little elk activity occurs here through any part of the winter. Consistent with this, browse utilization measurements taken in the spring reflect a very low level of use in these areas. Moose abandon willow communities between 6800 and 7400 feet in elevation around the end of January and do not return until the end of April. Utilization at these sites is higher. Elk seem to be forced to leave the willow communities in "moose habitat" several weeks earlier than moose and do not seem to return in the spring. In the "best moose habitat," elk numbers are less than moose numbers. Similar work conducted in Yellowstone Park at an elevation of about 6500 feet provides the opportunity for comparisons. In these areas, the willow is available to ungulates much of the winter and elk numbers are much higher.

TITLE: Effects of disturbance by cross-country skiers on elk in northern Yellowstone National Park.

AUTHORS: E. Frances Cassirer and Ernest D. Ables

AFFILIATION: Dept. of Fish and Wildlife Resources, University of Idaho, Moscow.

DATE OF REPORT: May 1990.

SUMMARY OF OBJECTIVES:

Movement and heart rate responses of elk to disturbance by people on foot and skis were examined in 3 areas of northern Yellowstone National Park. Objectives were to determine at what distances skiers disturbed elk, how far elk moved in response to disturbance, what factors influenced elk responses, and how long elk were displaced following skier disturbances. Energetic costs of movements and effects on energy balance over the course of the winter were estimated. Baseline heart rates of elk were documented, and the magnitude and duration of heart rate increases were assessed as an index to the degree of human disturbance in Mammoth Hot Springs and the Lamar River drainage.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. Elk in the Lamar Valley and Stephen's Creek areas were disturbed when people were at average distances of 573 m. These elk moved an average of 1.88 km when disturbed. They temporarily left the drainage and their home range core areas and moved to higher elevations, steeper slopes, and into forested areas when disturbed. Average return time to the drainage was 2 days. Skier numbers did not affect elk flight distances or distance moved.

2. Elk in Mammoth Hot Springs were less disturbed by human activity than those at Lamar and Stephen's Creek, but increased responses when disturbed outside areas consistently used by people.

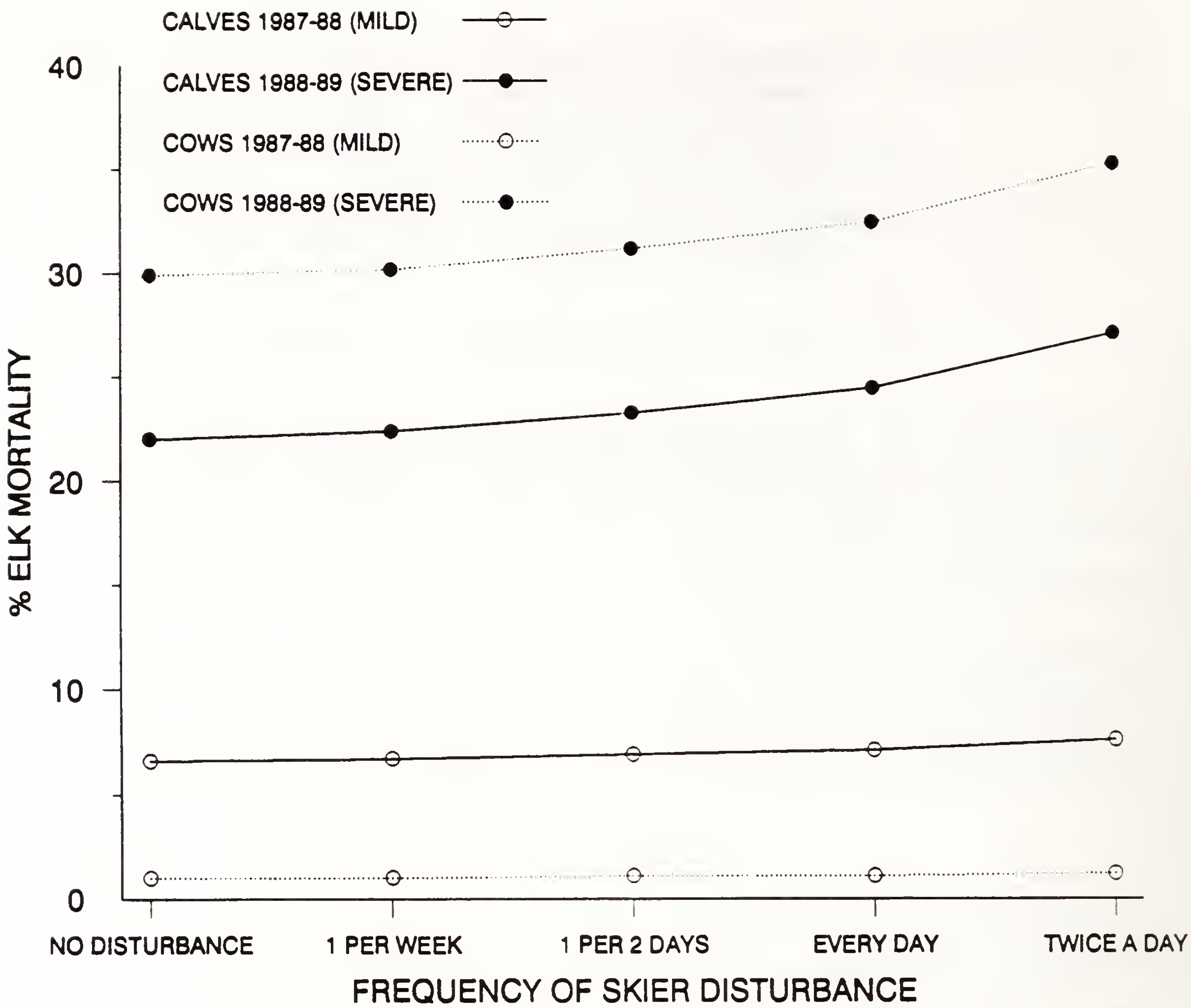
3. Elk in Lamar and Stephen's Creek expended an estimated 365 kcal for locomotion per disturbance. Potential negative effects of these additional energy costs on mortality and reproduction would be greatest when elk were in poor physical condition going into the winter, or when forage availability and quality on the winter range were low.

4. Heart rate responses to disturbance were greatest when elk were disturbed by people on foot or skis. Heart rate responses confirmed observations of

behavioral responses to disturbance and heart rates generally returned to normal before maintenance behavior was resumed. Undisturbed heart rates of elk in Lamar were lower than those of elk in Mammoth Hot Springs during February and March. Baseline heart rates of elk in Mammoth Hot Springs were lowest in February, and increased 76% between February and May.

5. Skier activity should be located at least 600 m from elk wintering areas.

6. Displacement of elk by skiers on the winter range would be minimized by concentrating skiers in forested areas with abundant topographic relief.



Predicted mortality rates of cow and calf elk in Lamar and Stephen's Creek with and without skier disturbances based on an average of 1.88 km moved per disturbance. This model, based on Hobbs (1989) publication <u>Linking energy balance to survival in mule deer: development and test of a simulation model</u>[1] incorporated data from Yellowstone and published research on elk and deer in other areas to simulate mortality rates during a mild winter (1987-88) and a normal winter preceded by a drought summer (1988-89). It does not address energy costs incurred if elk are displaced to lower quality habitat by skiers, or sublethal effects of reduced fat reserves such as lower reproductive rates or calf survival. Skier disturbances were more likely to affect mortality rates if elk were disturbed every other day or more, and would potentially have the greatest affect when accompanied by severe environmental conditions.

[1] Wildlife Monograph No. 101.

TITLE: Population characteristics of mountain lions in the Northern Yellowstone Ecosystem

AUTHORS: Kerry M. Murphy and Maurice G. Hornocker

AFFILIATIONS: The Wildlife Research Institute at the University of Idaho, Moscow

PUBLICATION REPORT STATUS: Continuing work. Manuscripts to be submitted to The Journal of Wildlife Management or Wildlife Monographs

PROJECTED PUBLICATION DATE: Unknown

DATE OF REPORT: April, 1990

SUMMARY OF OBJECTIVES:

The objective is a thorough documentation of population parameters of mountain lions on the northern winter range

SUMMARY OF MOST SIGNIFICANT FINDINGS:

Mountain lion densities on the northern range during winter 1989-90 was 13-23 mi^2/lion. Sex ratios among adults were 2 females: 1 male. Winter home ranges of 8 females and 3 males averaged 19 mi^2 and 27 mi^2, respectively, calculated using the convex polygon method. Home ranges of female lions overlapped up to 70%, but ranges of males were nearly unique. Size among 10 litters born to study area females since the beginning of study was 2.8 kittens. The mortality rate among 28 kittens from birth to independence was 75%. Among 9 mortalities to adult lions, sport harvest, fighting with other lions, and disease accounted for 6 (66%), 2 (22%), and 1 (11%) losses, respectively.

TITLE: Development of a Scaled Index of Winter Severity for Animal Studies in Yellowstone National Park.

AUTHORS: Phillip E. Farnes, Water Supply Specialist

AFFILIATIONS: Soil Conservation Service, Bozeman, Montana

PUBLICATION REPORT STATUS: Will be submitted to 1991 Western Snow Conference and possibly other symposiums.

PROJECTED PUBLICATION: Proceedings of Western Snow Conference.

PROJECTED PUBLICATION DATE: Mid-1991

DATE OF REPORT: May 1990

SUMMARY OF OBJECTIVE: Develop an index of wintering conditions that is flexible, easily interpreted by both professionals and lay persons and based on readily available data.

SUMMARY OF THE FINDINGS:

1. This scaled index of winter severity (SIWS) involves calculation of a probability analysis of minimum daily temperatures, snow water equivalent (SWE), snow depth, snow density and precipitation or SWE accumulation above a threshold level. Data is obtained from existing National Weather Service (NWS) Climatic Stations and Soil Conservation Service (SCS) snow courses and SNOTEL sites.

   Most of the Data and Statistical procedures are available through the Centralized Forecast System (CFS) on the SCS snow survey computer in Portland, Oregon. Access to CFS is available via modem and terminal.

2. The weighting of each parameter can be adjusted to represent the effect on different species.

3. Two or more stations can be combined to represent conditions on the larger wintering ranges.

4. The index rating is scaled from +4.0 for the mildest winter to -4.0 for the most severe winter with 0.0 being average. The scaling of this index makes it easy for wildlife managers and the general public to evaluate the mildness or severity of a given winter. Also, the procedure can be used to accumulate months as the season progresses and to assess conditions each month.

<u>Rating Scale</u>

+4.0 very mild	+1.0 slightly mild	-2.0 moderately severe
+3.0 mild	0.0 average (normal)	-3.0 severe
+2.0 moderately mild	-1.0 slightly severe	-4.0 very severe

5. A spring severity index can also be calculated to represent young mortality due to weather conditions and combined with the winter index to relate population trends to weather conditions.

6. An example of scaled index of winter severity for the Mammoth area is shown in figure 1.

The SIWS is the combined weighting of 0.4 X TMIN + 0.4 SWE +0.2 PRECIP for 1948-1990. TMIN is the accumulation of daily minimum temperatures below 0 F at Yellowstone Park climatic station (Mammoth), and presents the severity due to cold temperatures. SWE is the sum of April 1 SWE at Crevice Mountain and Lupine Creek snow courses and represents severity due to snow accumulation. PRECIP is the June plus July precipitation for the summer preceding the winter and represents the severity due to reduced forage production on the winter range. These weights and indexes can be adjusted to represent any specific condition that may have a bearing on the severity of a winter for any specific area, for any specific species or any specific area (where there are available data) or can be used as a general index.

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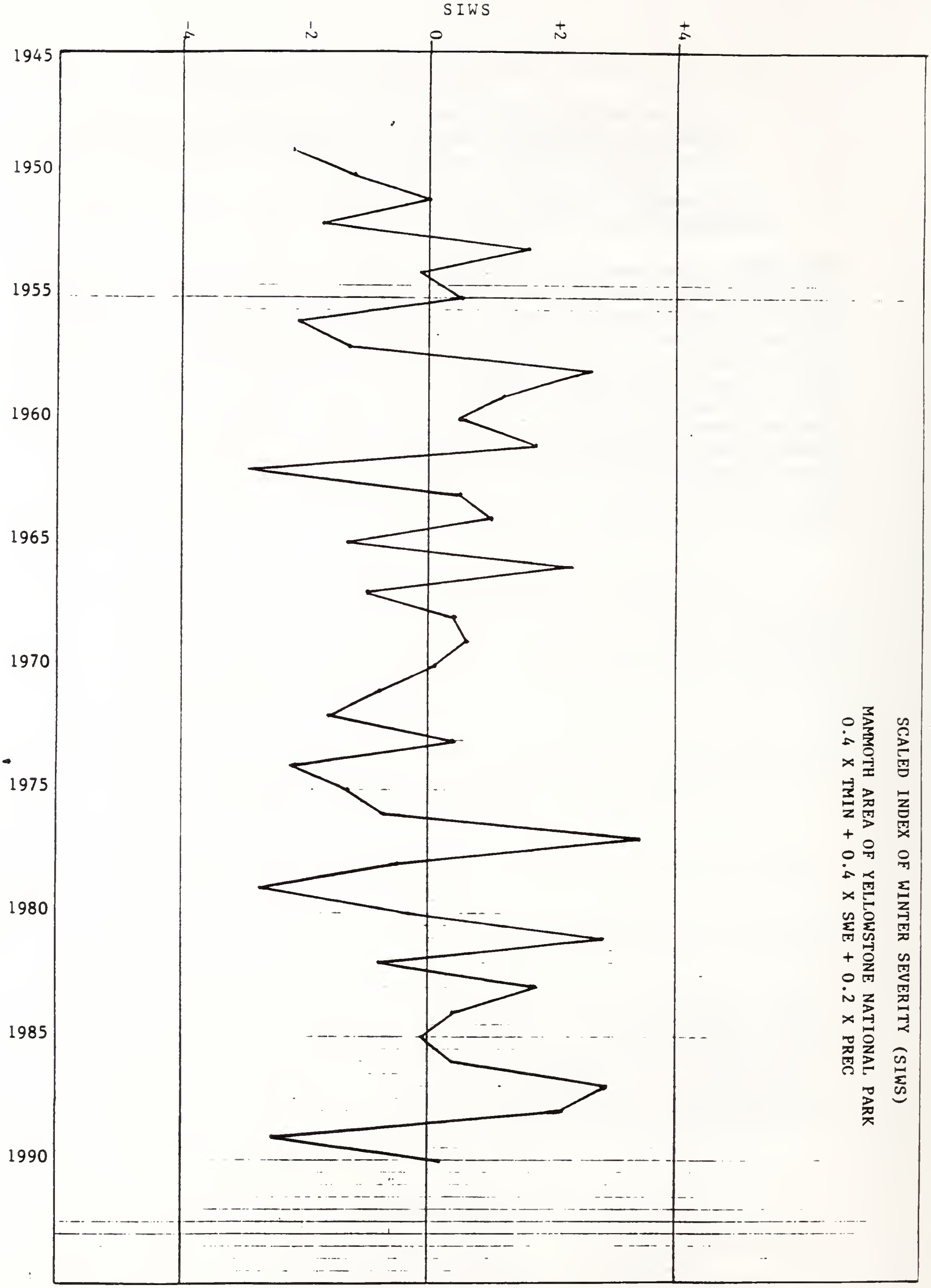


SCALED INDEX OF WINTER SEVERITY (SIWS)
MAMMOTH AREA OF YELLOWSTONE NATIONAL PARK
0.4 X TMIN + 0.4 X SWE + 0.2 X PREC
SIWS
-4
-2
0
+2
+4
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990

TITLE: Physiological assessment of winter undernutrition in elk of Yellowstone National Park.

AUTHORS: Glenn D. DelGiudice, Francis J. Singer, and Ulysses S. Seal.

AFFILIATIONS: Research Service, U.S. Veterans Affairs Medical Center and Yellowstone National Park.

PUBLICATION REPORT STATUS: Submitted to The Journal of Wildlife Management.

PROJECTED PUBLICATION: The Journal of Wildlife Management.

PROJECTED PUBLICATION DATE: ?

DATE OF REPORT:

SUMMARY OF OBJECTIVES:

This study physiologically assessed and compared the extent of undernutrition in elk (cow:calf groups) on the lower, middle, and upper portions of the Northern range, and on the Madison-Firehole range during winter 1987-88. Physiological assessments were accomplished by chemical analysis of elk urine excreted in snow. This technique permitted direct assessment of the physiological status of elk with minimal disturbance. Findings were related to differences in snow cover, herd composition, and elk distribution.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. Urinary excretion of urea (the end-product of dietary and body protein metabolism), sodium, potassium, and phosphorous varied within the four sampling areas as winter progressed and differed among the areas during each of four sequential sample collections (early January to late March).
2. Association of increased renal excretion by elk of urea

nitrogen with diminished excretion of potassium and sodium by early March, reflected progressive undernourishment. Data suggested accelerated net catabolism of body protein in elk across the Northern range and on the Madison-Firehole range that continued through at least late March.

3. Elk on the upper Northern range were in the poorest condition during early winter. Approximately 10% of the Upper elk were exhibiting metabolite data indicative of prolonged undernutrition and were relying heavily upon body protein as an alternate energy source. At this time elk density was greatest on the upper Northern range (44 elk/km^2), and snow cover was deeper than on the lower and middle portions of the range. Calf:cow ratios were lowest among Upper elk than middle and lower elk.

4. By early March, a portion of the Upper elk subpopulation had migrated to lower elevations. Elk density decreased to 14 elk/km^2 on the upper Northern range and the calf:cow ratio decreased by 50%. Elk density remained stable on the middle (28 elk/km^2) and lower (34-37 elk/km^2) Northern range during the same interval, but calf:cow ratios decreased by 48 and 35%, respectively. By early March, urinary metabolite data indicated prolonged undernutrition in approximately 13.5 and 10% of the Middle and Lower elk, respectively. None of the remaining Upper elk exhibited data suggesting prolonged undernutrition.

5. By late March, the proportion of Middle and Lower elk experiencing prolonged undernutrition declined dramatically; however, three times as many Middle elk compared to Lower and Upper elk, exhibited this nutritional status.

6. Physiological data suggested that Madison-Firehole elk, occurring at much lower densities, but in an area of notably greater snow cover than on the Northern range, benefited nutritionally by using the snow-free thermal areas. At Madison-Firehole, prolonged undernutrition peaked during late March (6.7%), about two weeks later than on the Northern range (7.1%).

7. During sample collections 1-4, 3.8, 0.6, 7.1, and 2.9% of elk throughout the Northern range exhibited urinary data indicative of prolonged undernutrition. This seemed to agree with an estimated mortality rate of less than 5.0%.

6. Our data tended to support Houston's (1982) contention that population density and winter severity (e.g., snow depth) were critical factors affecting natural regulation of the elk population via nutrition. However, in contrast to past studies, the data yielded by sequential collection and chemical analysis of urine in snow, additionally facilitated assessment of the nutritional status of elk that survived winter.

7. Furthermore, our data suggest that prolonged deep snow (84 cm during April) and restriction of Madison-Firehole elk to thermal areas might result in a proportional winterkill that

is ultimately greater than on the Northern range.

Winter Foraging Behavior of Elk and Bison in Yellowstone National Park, Wyoming.

Gillian Bowser

National Park Service, Yellowstone National Park, Wyoming.

April, 1990

Summary of Objectives:

Foraging behavior is one way to quantify the impacts of environmental parameters on animals. These parameters include snow depth, elevation, and winter severity (precipitation, temperature, and snow density). Mechanisms affecting herd movement and wintering locations can be identified by quantifying the influence of weather parameters on foraging behaviors such as bites, translocations, and rates of movement within or between craters.

This study examined the following hypotheses:

- There should be a functional relationship between environmental parameters such as snow depth or density, and foraging behaviors.
- Foraging data correlates with animal physiological condition and food habits.
- Environmental factors are measurable and influence observable behaviors in foraging animals.

Methods:

- Animals were observed using zoom spotting scopes for fixed intervals (observation bouts) following Altmann (1972) focal animal techniques.
- Behaviors were classified as head movements (swings, bites, chews, pulls, etc.) or as body movements (steps, paws, interactions with other individuals, etc.).
- Behaviors were analysed as behavior observations--the occurence of a particular behavior per observation bout; translocations--frequencies of body movement behaviors per number of bites during an observation bout; snow movement behaviors--frequencies of bites per swings, paws, nose pushing during an observation bout.
- Statistical analyses were performed on behavior occurrences (bites per unit time), or behavior frequencies (bites per swing, bites per step, etc.) for each

location. Locations were compared by snowdepth and water equilivalent using Soil Conservation Service data.

Summary of Most Significant Findings:

- There were significant differences between locations for all foraging behavior classes in bison.
- Northern range sites were significantly higher in all behavior frequencies than interior sites for bison. Movements between craters occurred more frequently for northern range sites than interior ones.
- Interior sites had fewer within- or between-crater behaviors than northern range sites. Animals appeared to re-use craters or stay within a particular crater for a longer period of time.
- Behavior ratios as indicators of snow movement and translocation (movements between craters, expressed as frequencies per step) were significantly different between sites for bison.
- Behavior ratios showed no significant functional relationship with snowdepth parameters, suggesting that the observed differences were due to otehr variables.
- Elk behaviors were highly variable between sites with no significant differences between locations.
- Snow density and water equilivalent did not vary between sites. Other parameters in the snowpack such as crystal types, and ice layers amy have a greater impact on foraging behaviors.

Recommendations and Conclusions

- Locations differ significantly in behavior ratios for bison, but not for elk. Future studies should concentrate on the effects of habituation and distributances on elk.
- Elk behavior ratios showed no significant differences. This result is in agreement with the lack of significance difference between snow density and water equilivant for each locations.
- Bison behavior ratios were significant in snow movement behaviors such as head-swings or pawing per bite, suggesting that these behaviors were more variable than translocation--steps per bite--behaviors. The variations in translocation behaviors may be governed by the amount of previous crater activity, and the size of the herd.
- Habituation effects may be subtle. The elk reduced bite rates in the presence of humans and vehicles while under observation.

- Snow characteristics within the snow column like ice layers and crystal sizes were not measured in this study. Snow characteristics potentially influence snow movement behaviors in ungulates by reducing food availability and increasing the energy required for foraging.
- Forage quality and quantity were not directly measured during this study. Future studies could examine forage aspects and ungulate food habits in greater detail.

The implications for foraging behavior projects for park research and management are wide-spread. Tourist influences on the winter survival of ungulates may be more subtle than measured by herd movements and range use. Reductions in ungulate bite rates in the presence of visitors suggests a hidden cost in the habitual human use of winter range areas by reducing food intake rates (frequency of bites per unit of movement).

The impact on ungulate survival during the winter may be snow quality (density, ice layers or crystal structure) and not quantity. The insignificant affect of varying snow depths on foraging frequencies suggests that other factors in the snow column may contribute to the different foraging rates. These factors include hoar frost concentrations near the ground surface, ice layers within the snow column, and snow pack shear conditions such as crystal-bonding and -strength.

In sum, foraging behavior studies provide detailed information on the effects of winter parameters on ungulates. This information, when combined with physiological data and food habits work, can provide a complete picture on the winter effects of ungulate populations.

TITLE: Collared elk response to the 1988 drought and fires in Yellowstone National Park.

AUTHORS: David J. Vales and Albert L. Harting.

AFFILIATIONS: Department of Fish and Wildlife Resources, University of Idaho and Research Division, Yellowstone National Park.

PUBLICATION REPORT STATUS: Rejected by the *Journal of Wildlife Management*. Resubmission to the *Wildlife Society Bulletin* is planned.

PROJECTED PUBLICATION: *Wildlife Society Bulletin*.

PROJECTED PUBLICATION DATE: Early 1991.

DATE OF REPORT: 21 May 1990.

SUMMARY OF OBJECTIVES:

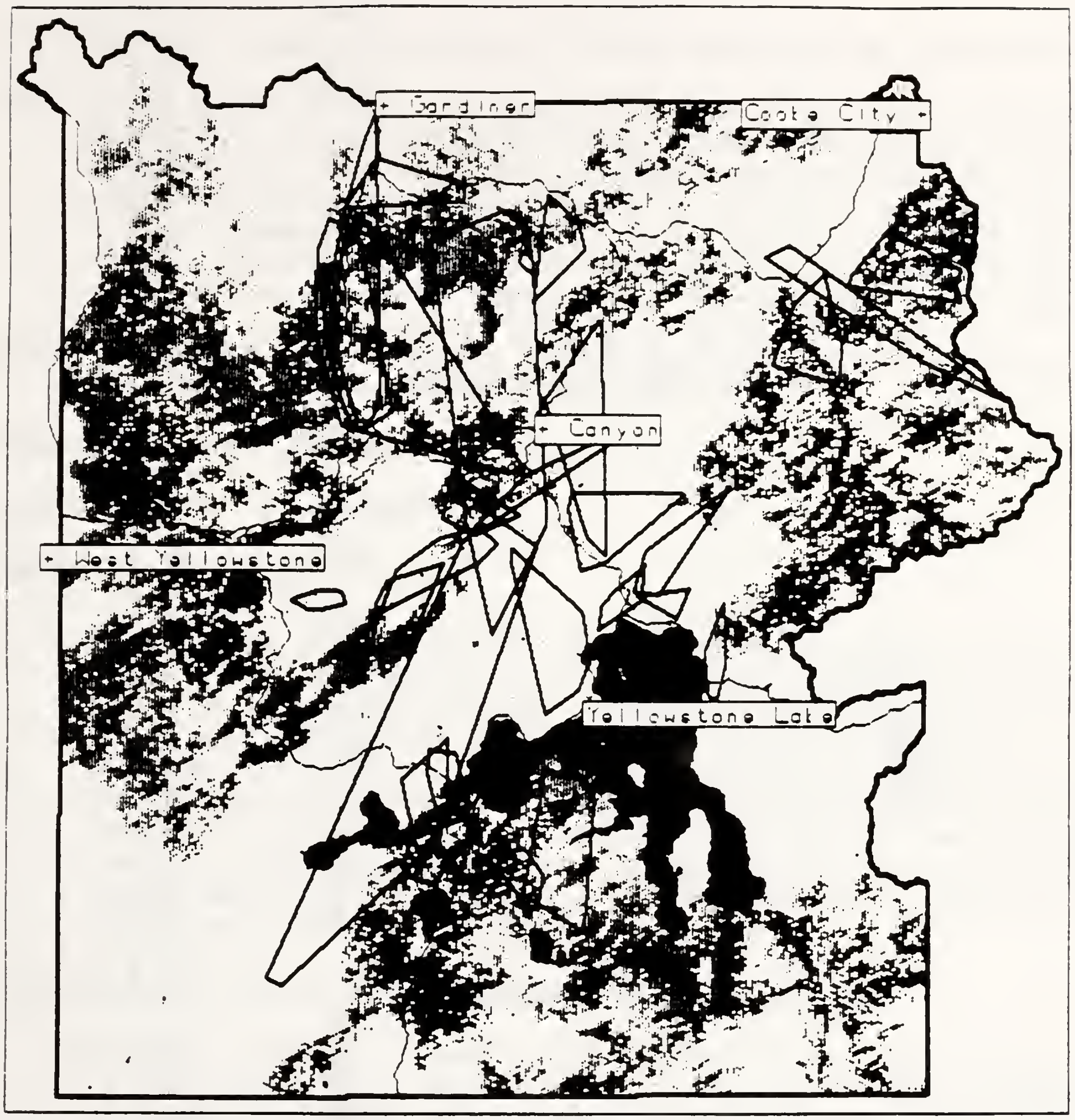
Thirty-two radio-collared adult elk from Yellowstone's northern winter range had been collared and monitored prior to the fires in 1988. For 27 of these animals we had summer 1987 home ranges; the other five were collared winter 1987-88. In this paper we evaluated the potential short-term impacts of the fires and drought on our collared elk. Data were presented on post-fire locations outside of pre-fire home ranges, changes in home range size between 1987 and 1988, and differences in timing of migration between 1987 and 1988. We examined relationships between these three potential response variables and percent of home range burned.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

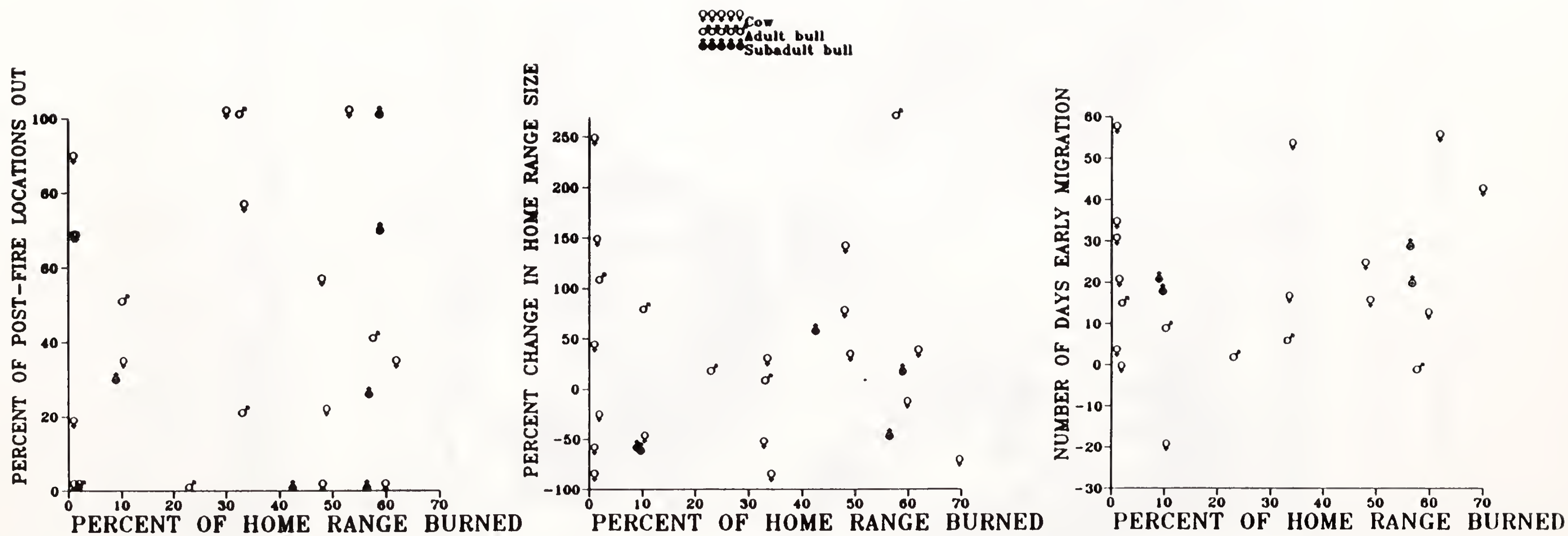
1. No collared elk died in the fires. Eight elk had 1% or less of their pre-fire summer home ranges burned, 4 had 2-10% burned, and 20 had more than 10% burned.

2. No relationships were found with (1) percent of post-fire locations outside of the pre-fire home range, (2) change in size of home range between 1987 and 1988, or (3) early migration to percent of home range burned. Lack of significant correlations indicated that there was no increased movement by elk on summer range that could be attributed to the fires.

3. Migrations averaged 19 days earlier in 1988 than in 1987. Because 6 cow elk least affected by fires migrated as many days earlier as 8 cows with more burning within their home ranges, we concluded that the drought of 1988 rather than the large-scale fires and associated activities influenced elk movements. Early desiccation of plants due to the prolonged summer drought was the most likely factor stimulating early elk migrations in fall 1988.



Burned areas and 100% minimum convex polygon pre-fire summer home ranges of elk in Yellowstone National Park. Dark tones represent lakes, light tones are burned areas.



Relationships of percent of post-fire locations outside of the pre-fire home range, percent change in summer home range size between 1987 and 1988, and number of days elk migrated earlier in 1988 compared to 1987, to percent of the pre-fire home range burned.

TITLE: Antler characteristics of northern Yellowstone elk: 1988.

AUTHORS: David J. Vales.

AFFILIATIONS: Department of Fish and Wildlife Resources, University of Idaho.

PUBLICATION REPORT STATUS: One paper on antler allometric relationships (predicting weight from dimensions) for *Wildlife Society Bulletin* co-authored with John Woods that includes data from Banff National Park. A second on population comparisons, also with John Woods, for *Journal of Wildlife Management*. A third on antler density, spongy tissue, and mineral characteristics and how they relate to age and habitat use by bull elk for *Journal of Mammalogy*. All are currently in preparation.

PROJECTED PUBLICATION: *Wildlife Society Bulletin*, *Journal of Wildlife Management*, and *Journal of Mammalogy*.

PROJECTED PUBLICATION DATE: 1991 and 1992.

DATE OF REPORT: 21 May 1990.

SUMMARY OF OBJECTIVES:

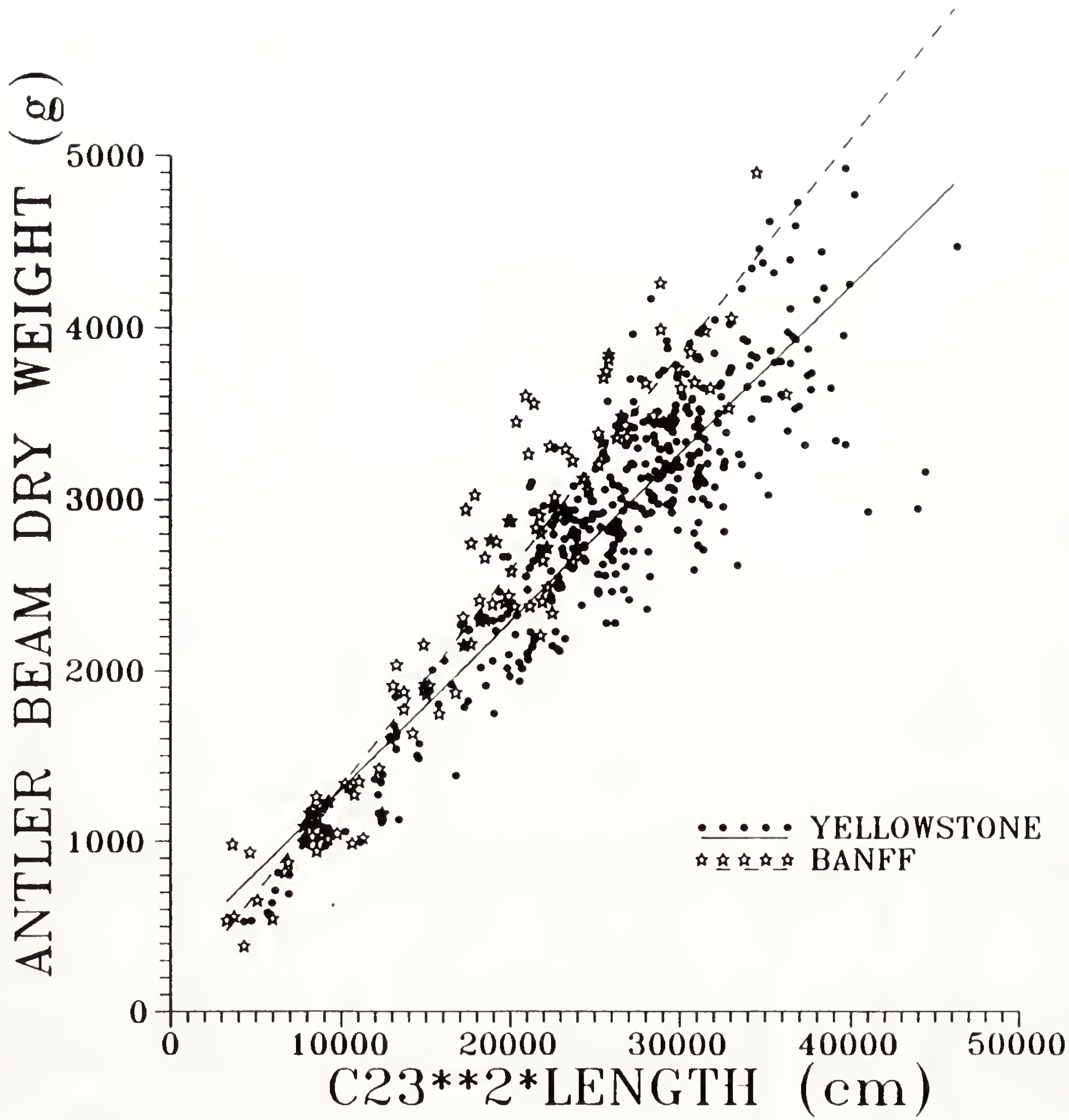
Antlers were cut off, weighed, and measured from bull elk dying naturally during the winter 1988-1989. Objectives were to: 1) predict antler weight from dimensions, compare allometrics among populations, and develop generalized equations if possible; 2) compare characteristics (weight, length) among populations, relate these to population levels, and infer potential nutritional effects on antler growth; and 3) relate antler density and mineral content to animal age, and tie in results with bull elk forage and habitat use data. The data can be used for future comparisons in Yellowstone as population size or nutritional conditions change.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

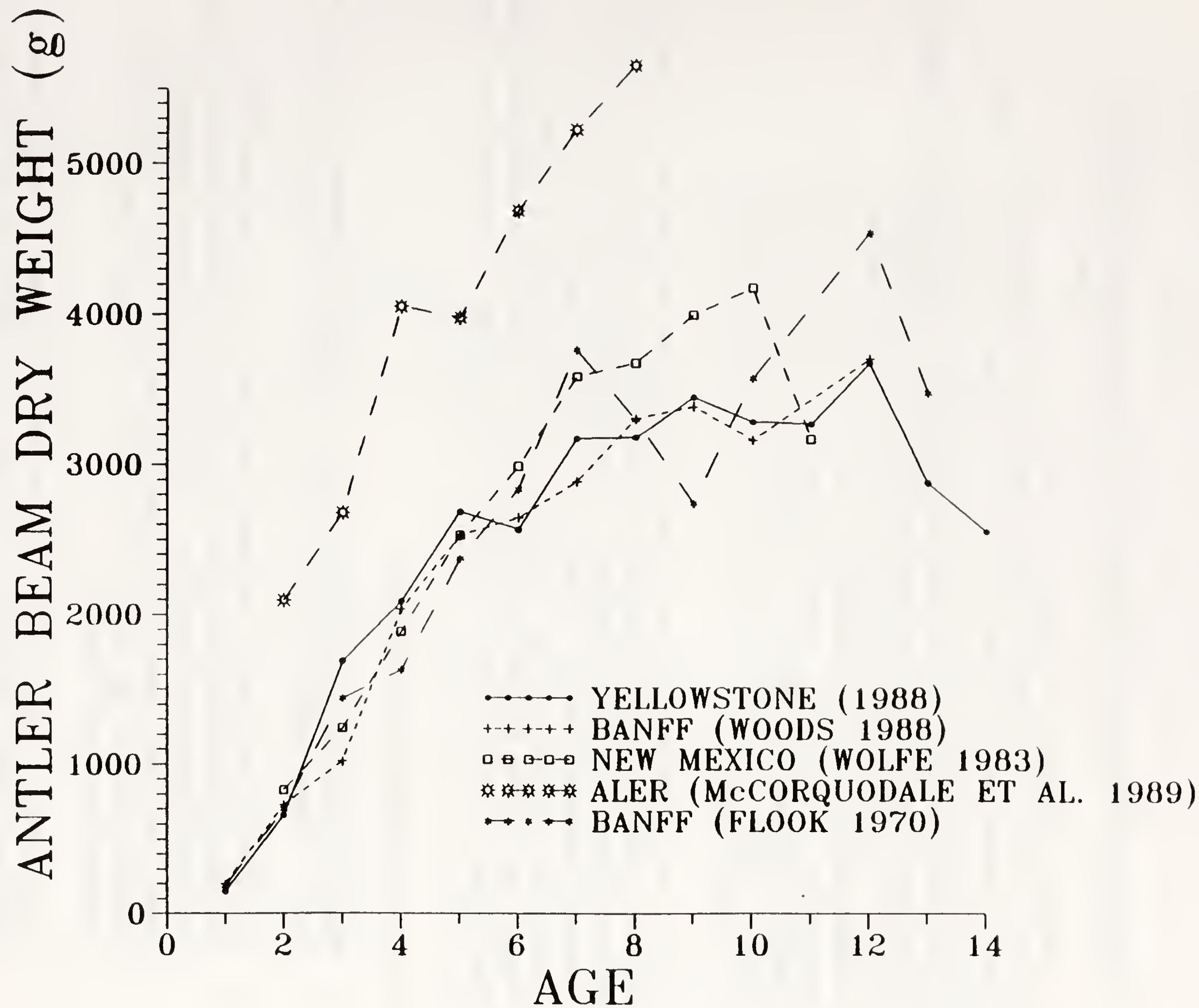
1. Antler mass was allometrically related to dimensions, but the single best predictor of mass was the 2nd-3rd tine minimum circumference squared x length, which gave a linear equation. Equations predicting mass differed between Yellowstone and Banff for ages 2+, but not for age 1 elk.

2. Antler mass of elk in Yellowstone peaked between ages 7-12. The mass over age relationship was similar to that in Banff at present, but less than that of New Mexico and eastern Washington (ALER). Populations in Banff and Yellowstone were at high levels; elk at ALER were colonizing and were at low numbers. Habitat, latitudinal, and growing season length influences need to be explored.

3. Moisture content of antlers averaged 13% for yearlings and 9% for bulls aged 2 and older. No significant differences were found between characteristics of left and right antlers. Antler main beam density averaged 0.95 g/cm^3 for yearlings and 1.21 g/cm^3 for bulls aged 2 and older. Spongy tissue area and mineral content analyses are being processed.



Relationship between dry weight of antler beams and the best predictor variable (minimum circumference between 2nd and 3rd tine squared times beam length) for Yellowstone and Banff National Parks.



Relationship between antler beam dry weight and age in four elk populations.

TITLE: Current distribution of beaver in Yellowstone National Park.

AUTHORS: Susan L. Consolo and Donay D. Hanson

AFFILIATIONS: Resource Management Office, Yellowstone National Park

PUBLICATIONS REPORT STATUS: Included in Wolves for Yellowstone? A Report to the United States Congress, Volume II, Research and Analysis.

PROJECTED PUBLICATION DATE: May 1990.

DATE OF REPORT: December 1989.

SUMMARY OF OBJECTIVES:

As part of on-going efforts to understand the ecology of Yellowstone's northern range and park riparian zones, and to monitor the status of controversial wildlife species, a sampling survey was initiated to document presence and distribution of beaver parkwide. Specific objectives for the initial survey were to 1) identify places with present or recent beaver activity, and 2) assess the likelihood that those sites could support long-term versus highly intermittent beaver activity.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. Much of Yellowstone National Park is marginal beaver habitat, but beaver have persisted here since the park's inception.

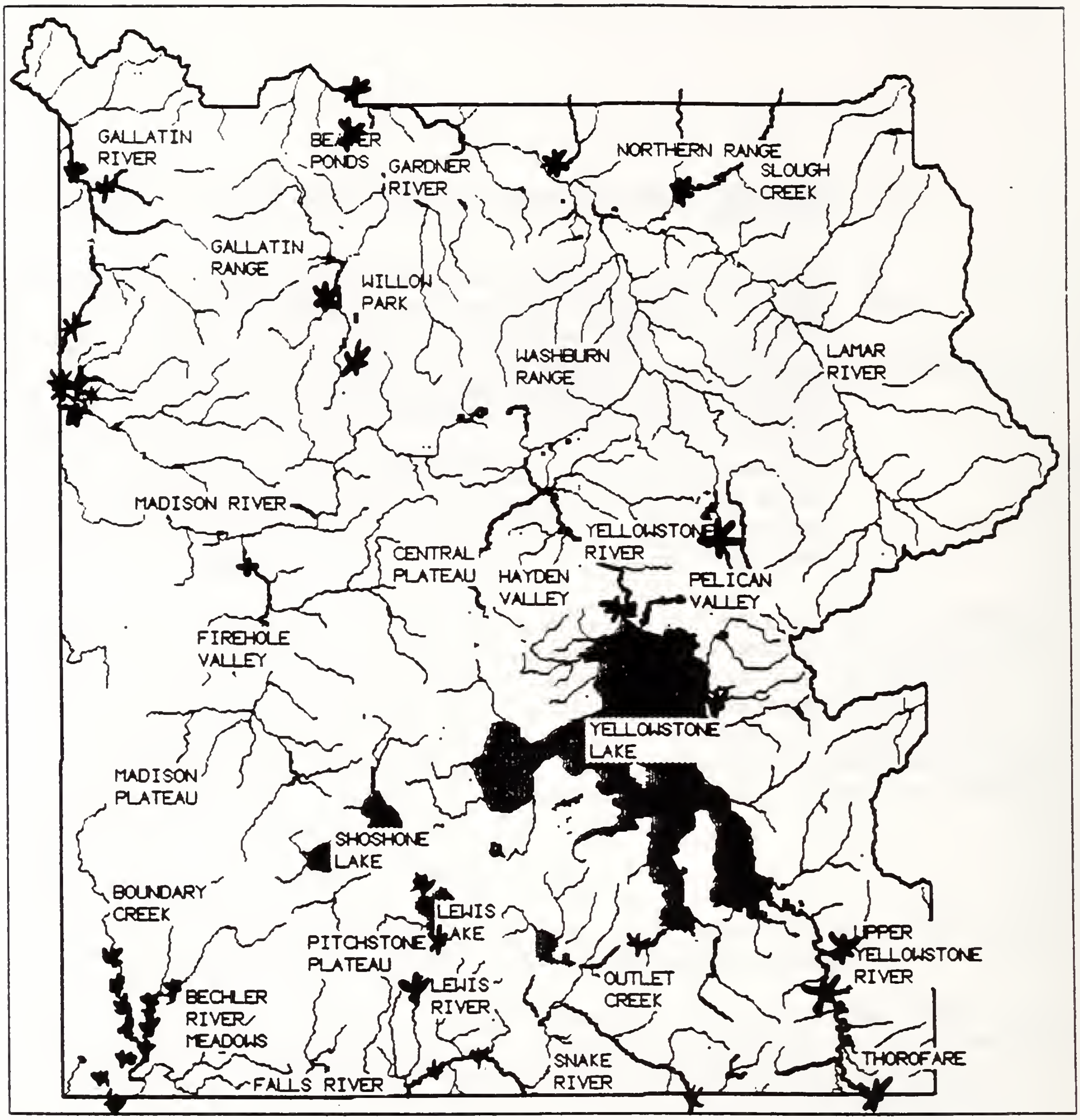
2. In 1988-89, 453 km of riparian habitat in Yellowstone (88% of targeted routes/sites) were surveyed to determine current presence and distribution of beaver. There were 43 stream segments or lakes that had signs of current beaver activity. 42 reliable observations of at least 27 individual beaver were collected during the survey period.

3. There were at least 26 locations with evidence of both present and previous beaver activity, at least 5 of which are on the northern range. Rivers such as the Yellowstone, Gardner, Lamar, and Slough Creek show signs of periodic beaver presence and likely support bank-denning beaver that are difficult to observe. Evidence of moderately persistent activity was found on those waterways, and also in the Beaver Ponds, Slide Lake, and Willow Park areas near Mammoth Hot Springs.

4. Signs of numerous, persistent beaver colonies were found in the upper Yellowstone River/Thorofare region, the Bechler region in the park's southwest corner, the lower elevation reaches of the

Gallatin River drainage, and portions of the Madison River drainage.

5. Observations of beaver and current sign should continue to be collected and surveyed on a periodic basis. Widespread fire activity of 1988 could potentially affect beaver distribution, depending on fire effects on willow and aspen communities as these species are often associated with persistent beaver colonies. However, as a number of stream characteristics have been found to positively correlate with colony size and persistence (Easter-Pilcher 1987), potential beaver habitat in Yellowstone's streams would be better assessed by using a comprehensive stream survey system such as that developed by Rosgen (1985) or Beier and Barrett (1987.)



Areas where beaver or present/recent beaver signs were observed in 1988-89.

TITLE: Elk forage responses in burned and unburned lodgepole forests.

AUTHORS: Francis Singer, James Reardon, Jack Norland, and Jill Oppenheim, Box 168, Yellowstone National Park, WY 82190

PUBLICATION REPORT STATUS: An article for Journal of Wildlife Management is planned.

SUMMARY OF OBJECTIVES:

1. To determine changes in plant species abundance and production in burned and unburned forests on elk summer range.

2. To determine any nutritional changes in elk forages after burning.

3. To determine any differences in elk preferences for forages between burned and unburned habitats. In particular, the hypothesis of Don Despain was investigated, specifically, that some forages species untouched in unburned areas are eaten in burned areas.

METHODS AND STUDY AREA:

1. The study area was located 4 miles southwest of Grant Village in a lodgepole pine forest-wet meadow complex that was partially burned in August of 1988. Three similar burned and unburned sites were selected for both forest and meadow. At each site 10 samples of each forage were collected. The forages were collected, dried and sent to the Composition Analysis Lab in Ft. Collins for analysis of protein content and digestability.

2. Plant sampling was conducted in 1990. Grazing exclosures were erected in forest and meadows in order to determine the amounts of herbage removed by elk. Four replicates of each treatment (grazing, burning) were available.

SUMMARY OF PROGRESS AND FINDINGS:

1. Protein content was higher in burned areas for all four forage samples collected in 1989 (Fig. 1). The magnitude of the increase in protein content is unprecendented in the scientific literature for elk forages. Our explanation for this observation is that most studies of elk forage responses have been conducted near cool fires, e.g. prescribed burns in forest understories, while the Grant fire was a hot wildfire.

2. We found no significant effect on protein content in elk forages in the meadows. These fires were cooler.

3. Digestibility was higher in three burned elk forages in the

forest understory, but not in elk sedge (Table 1). No significant difference was found in any burned elk forages in the meadows. In conclusion, digestibility followed the same trend as for protein content--differences were detected only where the fires were hotter.

4. Vegetation composition of forest understories was dramatically altered by the fires. Huckleberry declined, and grasses and fireweed greatly increased.

5. More intensive field sampling is continuing in 1990.

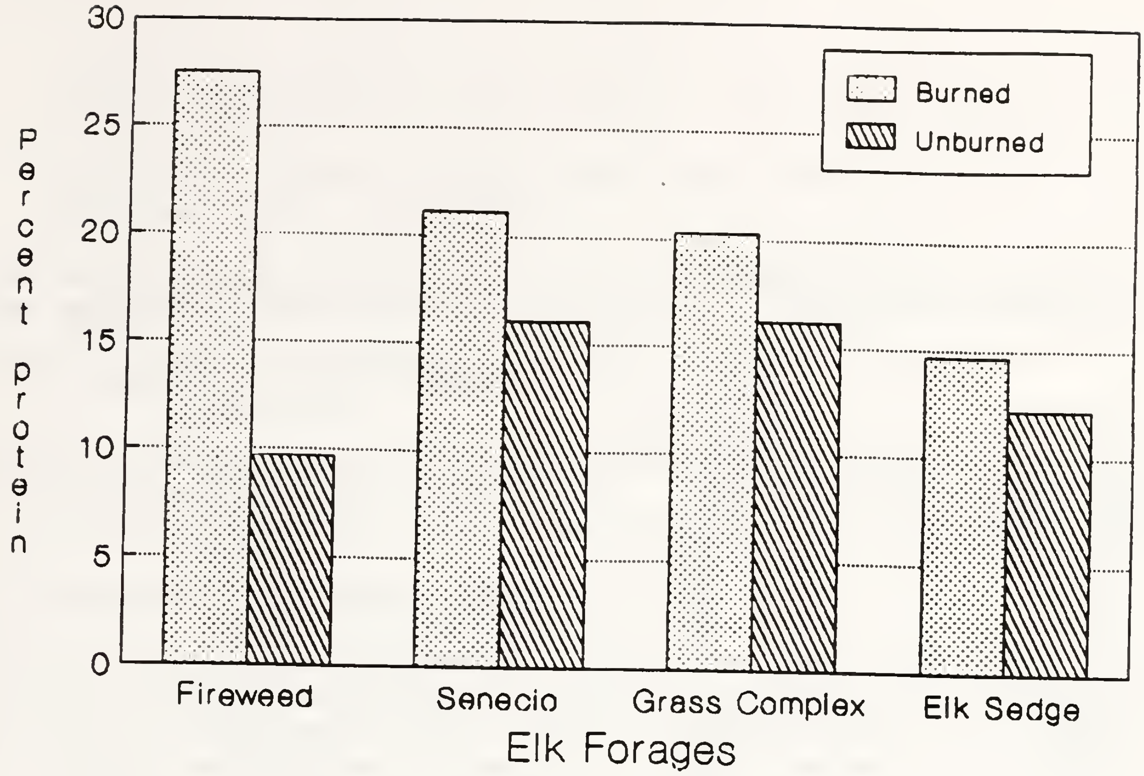


Fig. 1. Percent protein in burned and unburned elk forages in lodgepole forest, 1989.

Table 1. Digestibility of elk forages in burned and unburned meadows and forest understories in the Grant Village area, 1989.

Forage	% Digestibility Burned	Unburned
Forest:		
Fireweed	75	62 *
Senecio	79	71 *
Grass	72	69 *
Sedge	66	64 *
Meadow:		
Forb	79	79
Grass	70	71
Sedge	66	67

TITLE: Effects of the fires of 1988 on elk calf survival rates.

AUTHORS: Francis Singer and Albert Harting, Box 168, Yellowstone National Park, WY 82190.

PUBLICATION PLANS: Journal of Wildlife Management article winter 1990-91.

SUMMARY OF OBJECTIVES:

1. To continue elk calf mortality studies the first two years following the fires of 1988. To compare data gathered on elk calf mortality before the fires to elk calf mortality after the fires.

SUMMARY OF PROGRESS AND FINDINGS:

1. Thirty-two neonatal elk calves were captured in the spring of 1990. Fourteen were captured in the Gardiners Hole study area, and 18 in the Lamar study area. Sixteen were captured by ground and 16 by helicopter. One transmiter was malfunctional, reducing the sample size to 32 calves.

2. We predicted elk calf survival would be improved after the first full growing season following the fires, due to nutritional enhancement of summer and winter ranges. Summer 1990 mortality rates of calves were in fact higher than any previous year (Fig. 1). Apparently, predators were more highly motivated to search for and chase calves in 1990, due to the paucity of winterkilled ungulates during the winter 1989-90.

3. We predicted elk calves would weigh more in 1990 than any previous year, due to range enhancement from the fires of the fall of 1988. This did not prove to be the case (Fig. 2), although 1990 calf weights were improved over weights in 1989 which followed the drought, fires and severe winter of 1988-89.

4. An original goal of this project was to determine the cause of the typically low calf ratios in the northern elk herd in fall and early winter. We have now established that those low fall ratios are due primarily to predation soon after birth of the calves, although accidents and sickness also takes some calves. The relative importance of predators was: grizzlies> coyote> black bear> golden eagle.

5. Houston (1982. The Northern Yellowstone elk. Macmillan) concluded that over-winter mortality of elk calves was density dependent in the northern herd, and was a potential population regulatory mechanism. We did not refute these conclusions. However, our 4-year study demonstrated that predation was more significant than winterkill in the first year mortality of calves (Fig. 3). Additionally, during our study, predation acted in a density independent fashion. For example, predation rates were highest the year of lowest elk numbers.

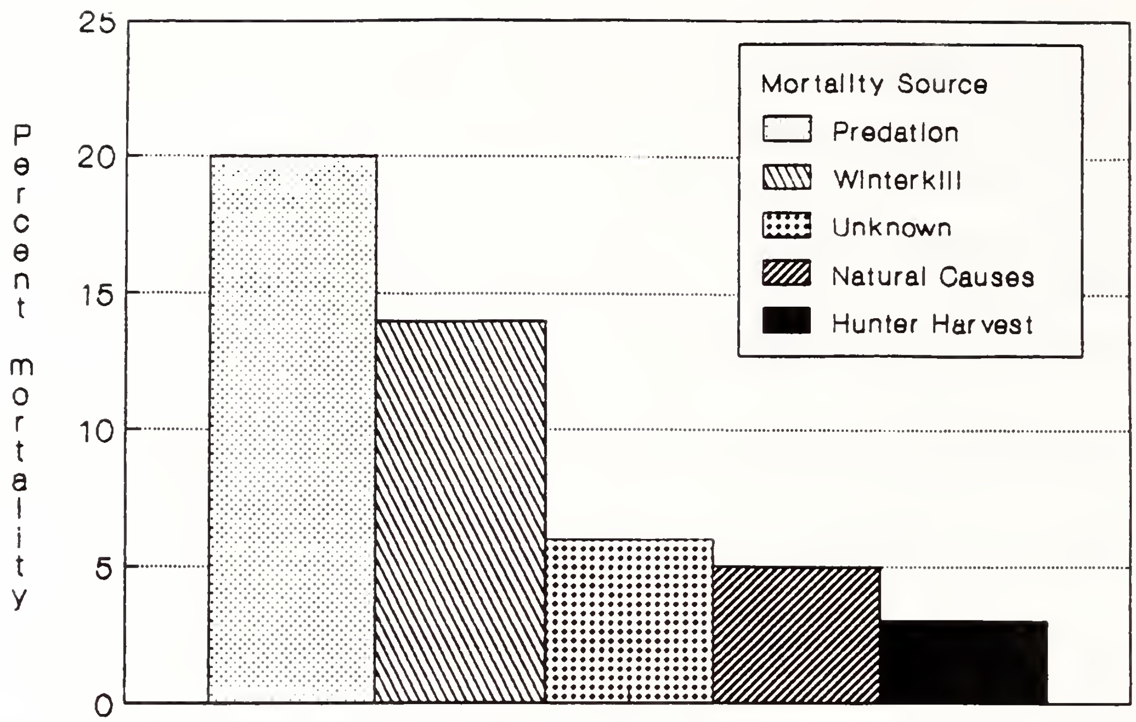


Fig. 3. Sources of elk calf mortality during the 1st year of life, 1987-1990, expressed as a percent of the original marked cohorts (n=128 marked calves), on Yellowstone's northern range.

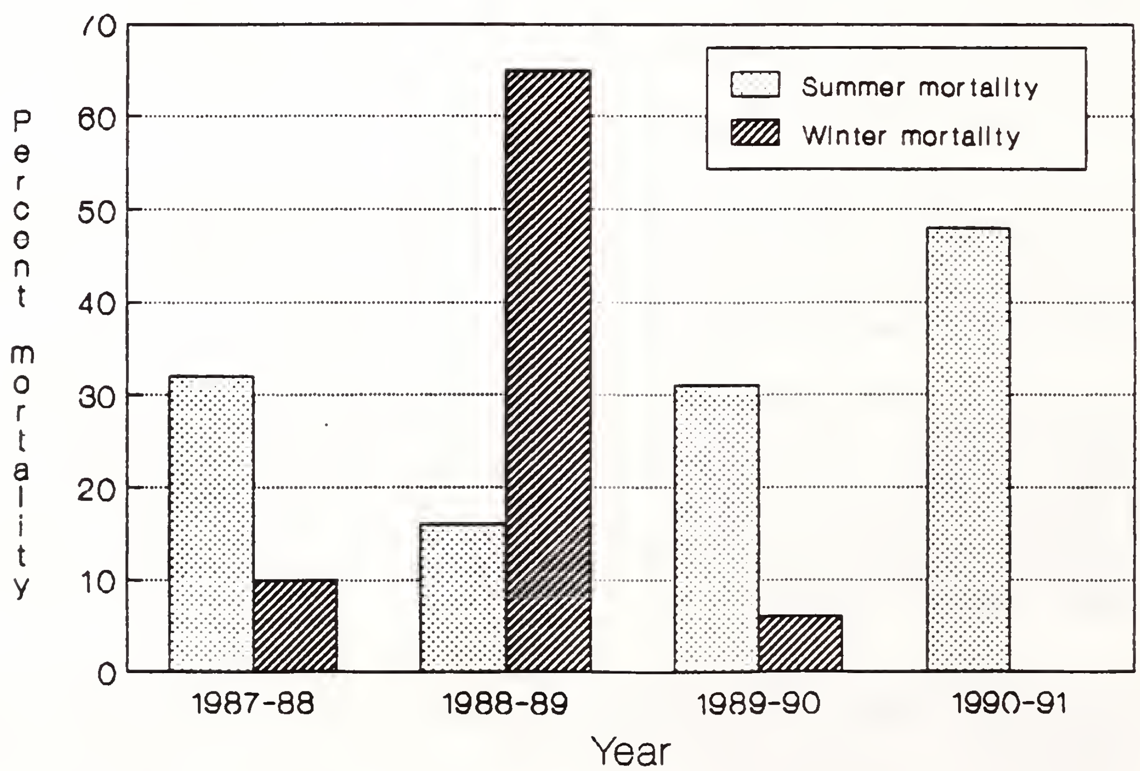


Fig. 1. Elk calf mortality rates, 1987-1990, on Yellowstone's northern range. Percent of initial samples of marked elk calves that died the first summer and the first winter after marking. No data is available yet for the winter of 1990-1991.

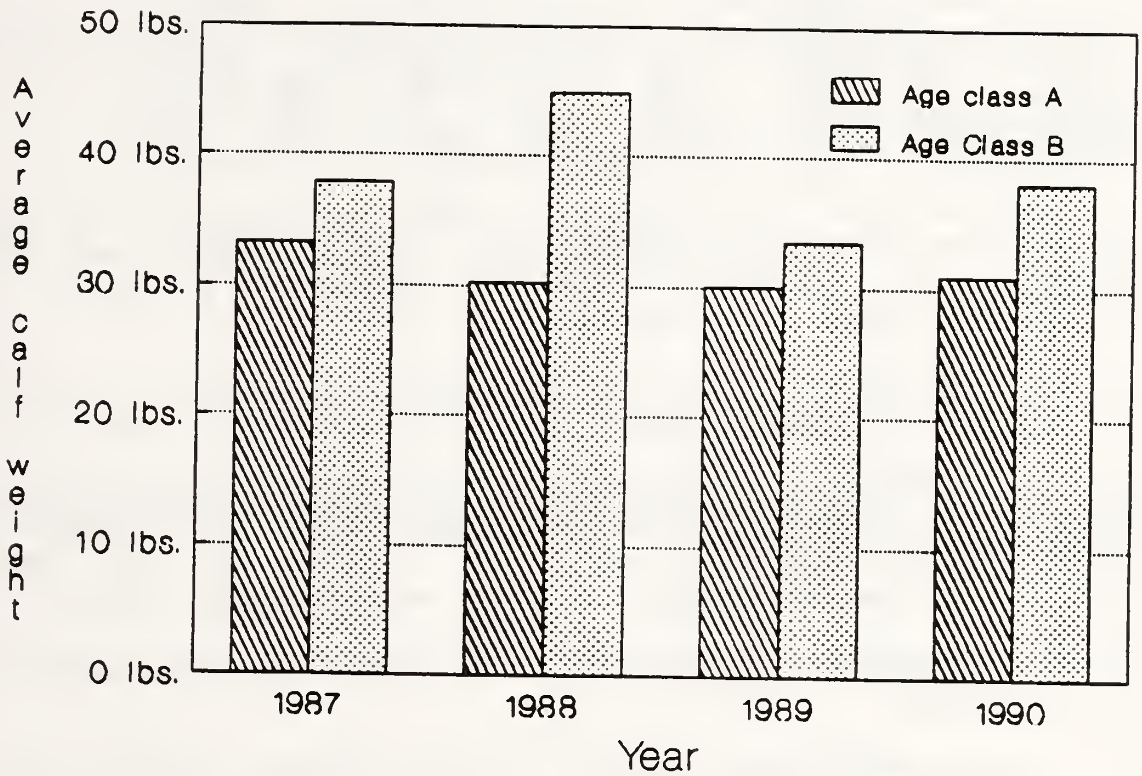


Fig. 2. **Elk calf weights in age class** A (0-1 day), **and age class** B (2-4 days), **on Yellowstone's northern winter range**, 1987-1990.

TITLE: Grazing responses of grasslands to ungulates on Yellowstone's northern elk winter range.

AUTHOR: Francis J. Singer

AFFILIATION: Research Division, Box 168, Yellowstone National Park, WY 82190.

PUBLICATION STATUS: Submitted to J. Range Manage. August 1990.

OBJECTIVES:

1. To determine the effects of ungulate grazing, mostly by elk, upon grassland species abundance, grassland production, grass nutritional quality, and grass heights and morphology.

CONCLUSIONS:

1. Biomass of two grasses, junegrass (Koeleria cristata) and thickspike wheatgrass (Agropyron dasystachum), was greater on grazed plots. Both of these two grasses are widely held to be increasers under grazing(Fig. 1).

2. No consistent difference was observed between 23 other grasses and 87 forbs between grazed and ungrazed sites (Table 1).

3. Minor differences in ground cover was observed on grazed sites. The percent of bare ground averaged about 38% greater on grazed sites, while cover by moss and lichens did not differ in a consistent fashion between grazed and ungrazed sites.

4. No increase in mortality of bunchgrass clumps was observed on grazed sites.

5. Grass morphology varied little between grazed and ungrazed sites. Vegetative culms were shorter on grazed sites, but the total number of vegetative culms did not differ. The heights and numbers of reproductive stalks did not differ between grazed and ungrazed sites.

6. Litter and standing dead vegetation averaged 4 times greater on ungrazed sites. This was a logical consequence of the lack of grazing.

7. There was a very large enhancement in protein and a minor enhancement in other mineral nutrients in 3 common grasses on grazed sites (Fig. 2, Table 2).

JUNEGRASS

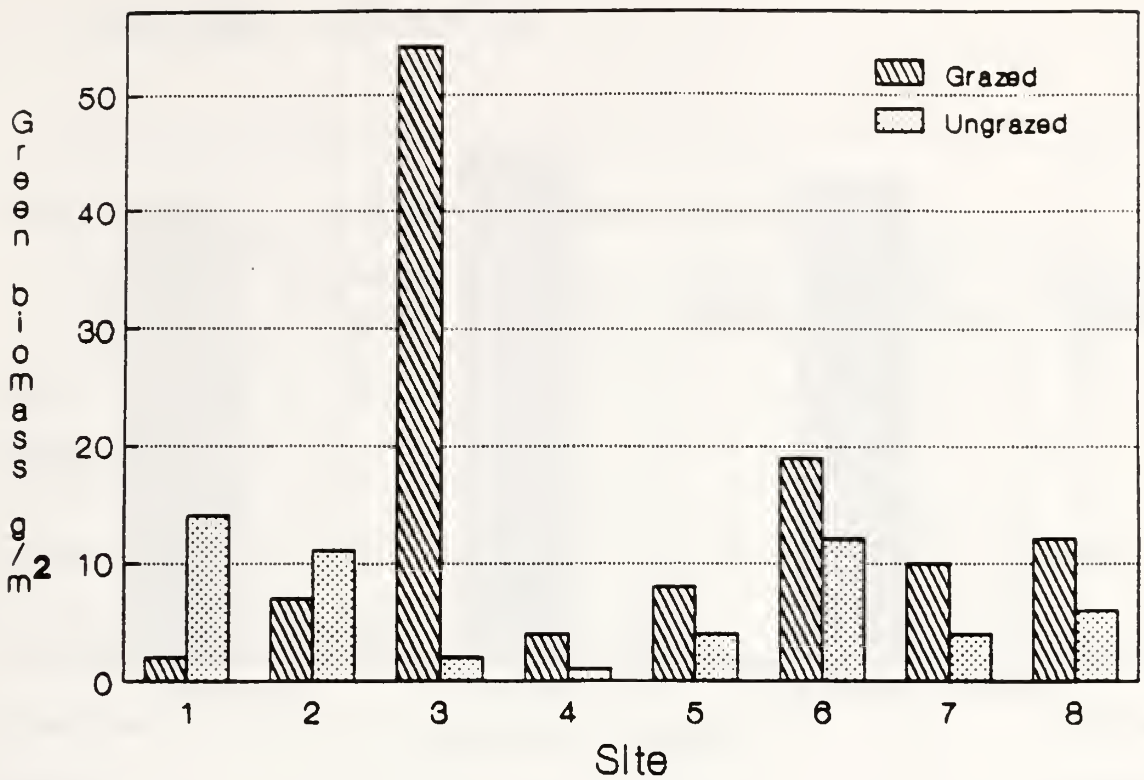


Fig. 1. Biomass of june grass on paired grazed and ungrazed (exclosed) plots on Yellowstone's northern winter range.

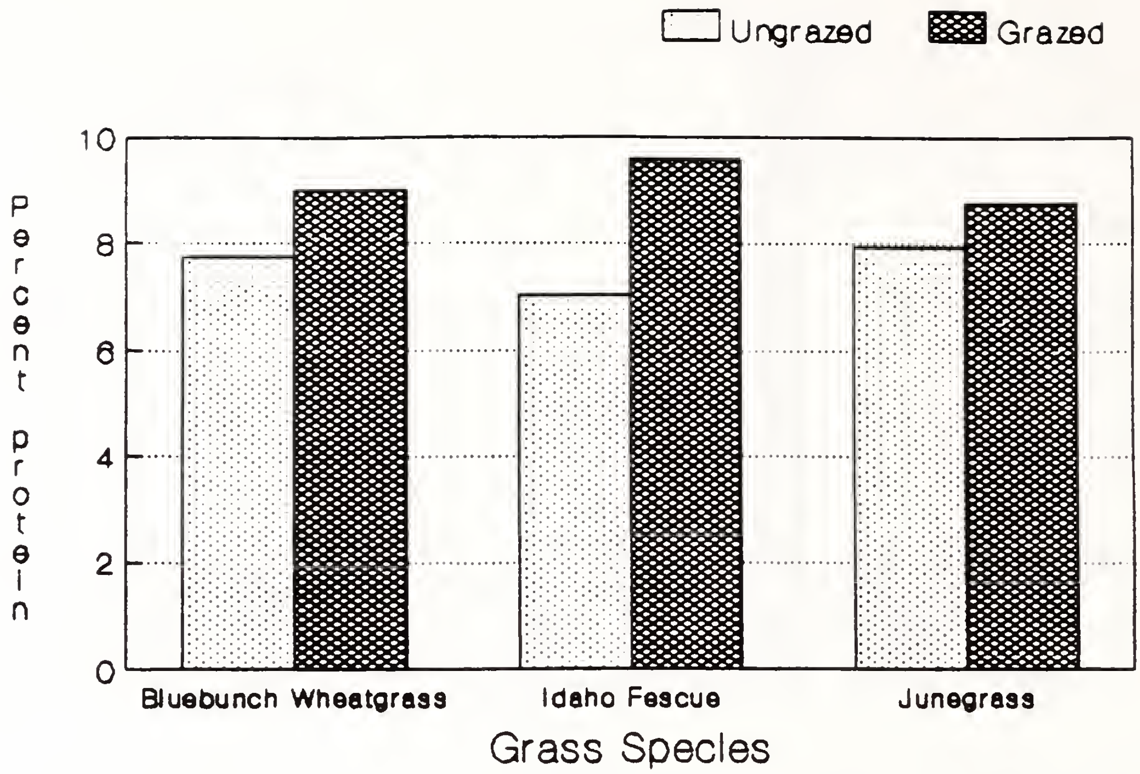


Fig. 2. Protein concentration in live tissue of three common grasses in grazed and ungrazed plots on Yellowstone's northern winter range.

TABLE 1. BIOMASS DIFFERENCE ON GRAZED PLOTS

PLANT SPECIES	NO. PAIRED PLOTS	MORE BIOMASS	LESS BIOMASS	NO DIFFERENCE	SUSPECTED EFFECT
Idaho fescue	5	1	2	2	none
Bluebunch wheatgrass	7	2	2	3	none
Bluegrass	5	2	0	3	none
Thickspike wheatgrass	3	2	0	1	none/inc.
Junegrass	8	6	0	2	increase
Litter	8	0	8	0	decrease

TABLE 2.

ENHANCED CONCENTRATIONS IN GRAZED SITES

	IDAHO FESCUE	BLUEBUNCH WHEATGRASS	JUNEGRASS
Ca	*		
P	*		
Mg	*		
K		*	
Mn			
Protein	*	*	*
Digestibility	* (+0.3%)	* (+ 8%)	* (+ 2%)
Fiber			
Ash	*		*

TITLE: Effects of the fires of 1988 on grasses and herbivory at the Blacktail Deer Creek exclosure.

AUTHORS: Francis Singer and Mary Harter, Box 168, Yellowstone National Park, WY 82190

PUBLICATION REPORT STATUS: Article for Journal of Range Management, spring 1991.

SUMMARY OF OBJECTIVES:

1. To document the effects of the fires of 1988 on grassland production and forage quality in grazed and ungrazed areas.

2. To document the effects of the fires of 1988 on soil moisture, seed effort, and spring grazing pressure in a grassland community.

INTRODUCTION:

Eight large grazing exclosures were erected in 1959 and 1962 on the northern winter range to monitor grazing influences by ungulates. Two of these exclosures were influenced by the large fires of 1988. These two exclosures are located on the south facing slopes just west of Blacktail Deer Creek. In the summers of 1989 and 1990, a study was initiated to determine the effects of the fires on elk forage abundance and quality in these grazed and ungrazed (exclosed) sites.

METHODS:

1. Plant cover was measured on 10 macroplots within each of the four treatments of burned and unburned, and grazed and ungrazed sites. Paired plots weres selected with similar slope, aspect, soil, and vegetation type.

2. Within each macroplot, 15-0.25m square subplots were randomly located. Cover by plant species, litter, rock, bare ground, moss, lichens, and animal plants was recorded.

3. Mann Whitnmey U tests were used to test for mean differences between the treatments of burning and grazing.

SUMMARY OF PROGRESS AND FINDINGS:

1. Ungrazed sites responded less rapidly to burning. Ungrazed (exclosed) sites had less plant cover the first summer after the fires (Fig. 1). Litter and standing dead vegetation averages 4 times greater inside of these exclosures (Singer in review). We suspect the fires inside of the exclosures were hotter as Wright and Klemmedson (1965) observed for ungrazed areas, and therefore, vegetation recovery was slower (Wright and Bailey 1982).

2. Grazed plots responded rapidly to the fires, and burned plots

had more plant cover the first season following the fires (Fig. 2). We suspect the fires were cooler on the grazed sites due to less litter. Also, grasses and forbs are less sensitive to burning late in the grwoing season (Wright and Bailey 1982) as occurred at the Blacktail Deer Creek exclosures. Increased soil nutrients following a fire may result in greater plant production.

3. In conclusion, burning of grazed grasslands resulted in more plant cover the first growing season following a fire in comparison to unburned grazed grasslands. However, the trend was the reverse for ungrazed (exclosed) grasslands. Apparently due to the accumulation of litter in ungrazed grasslands, burned sites had less vegetative cover the first season following the fires.

4. Plant nutrient quality (protein, digestibility, other nutrients) has been analyzed by a laboratory, but the results have not yet been analyzed statistically.

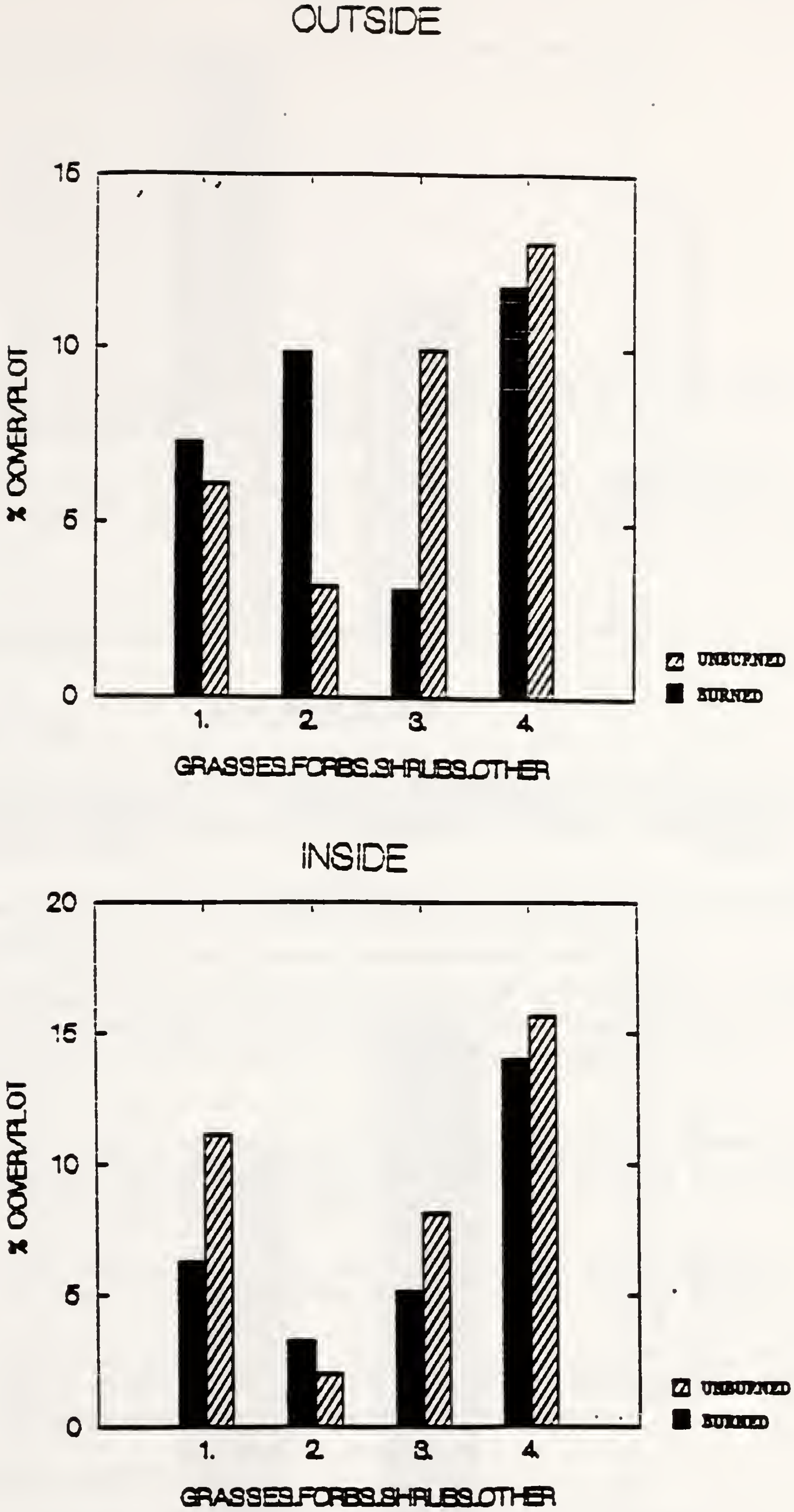


Fig. 3. Vegetative recovery by forage class the first year following the fires in grazed (outside) and ungrazed (inside) plots at the Blacktail exclosures, 1989. Grazed sites responded more quickly to the fires. Forbs responded more quickly than grasses, and grasses responded more quickly than shrubs.

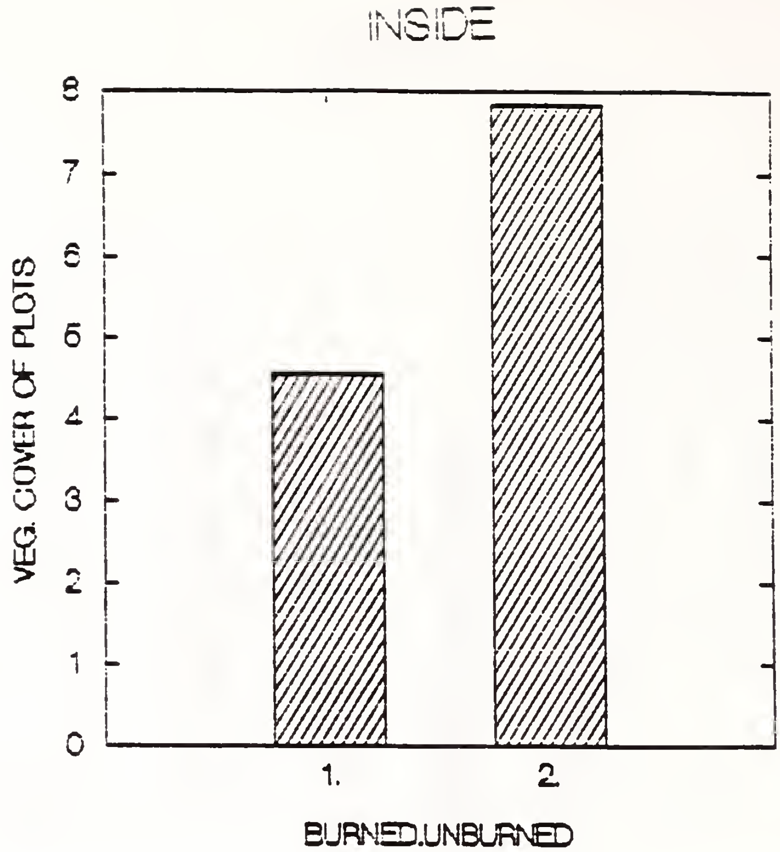


Fig. 1. Vegetative cover of ungrazed (exclosed) burned and unburned plots inside of the Blacktail Deer Creek exclosures in 1989.

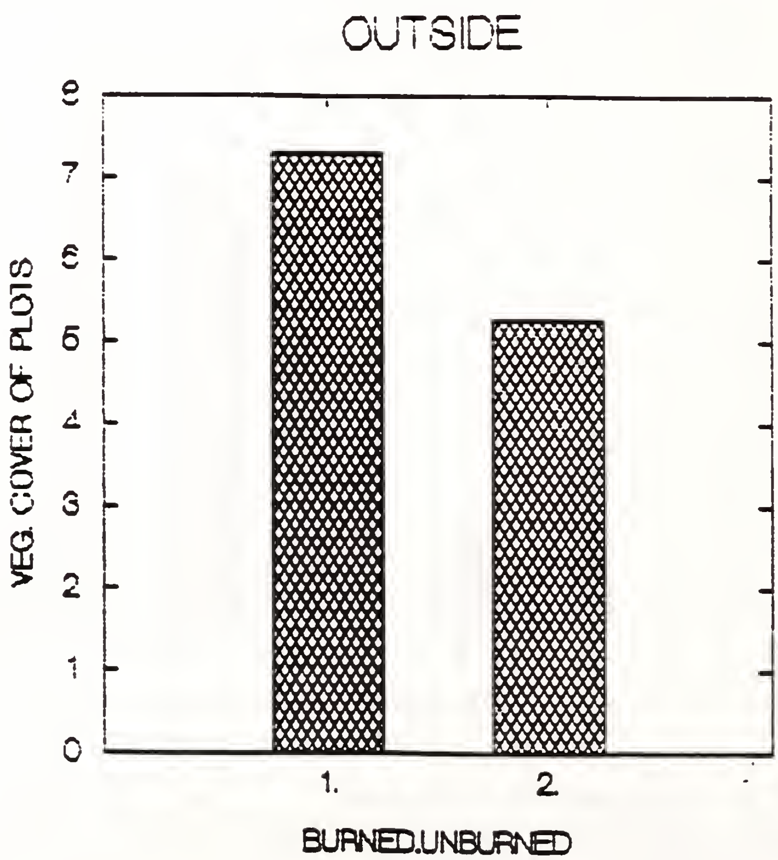


Fig. 2. Vegetative cover in grazed burned and unburned plots located outside of the Blacktail Deer Creek exclosures in 1989.

TITLE: WILLOW SPECIES ABUNDANCE, HERBIVORY, AND THE ROLE OF SECONDARY COMPOUNDS ON THE NORTHERN ELK WINTER RANGE.

AUTHORS: Francis Singer, Lauryl Mack, Research Office, Yellowstone National Park, WY 82190; and Rex Cates, Bringham Young University, Provo, Utah.

PROJECTED PUBLICATIONS: Ecology, Moose Conference in 1991.

SUMMARY OF OBJECTIVES:

1. To describe the distribution and abundance of willows in three drainages located in the northeastern corner of Yellowstone's northern range.

2. To sample the utilization patterns on these willows by large herbivores.

3. To investigate the implications of herbivory, climatic change, and primary sucession upon willow stature, vigor, and nutritional status and, in particuliar, to investigate three primary hypotheses:

   a. That a drier climate in the early part of the twentieth century, especially 1919-1936, contributed to a decline in willows and/or willow stature.

   b. Water and/or browsing stressed willows produce fewer secondary defense compounds than non-stressed willows.

   c. The fires of 1988 may promote vigor and growth in willows and production of secondary compounds and enable some burned willows to escape the height of browsing.

SUMMARY OF FINDINGS SINCE 1989:

1. Willow heights were classified into three categories on the northern range; low stature willows were from 1-37.2cm, intermediate stature was 37.3-176.2cm, and tall stature willows were 176.3cm and above. The mean height of all willows across the northern range was 106.7cm + 69.5. Using these categories, there are two "tall" willow communities (Lower Slough Creek and Soda Butte Creek), two communities which are "low", (Mammoth and Lamar willow belts), and all other communities fall within the

"intermediate" height category. Winter utilization of tall stature willows averaged 38.6% from 1987 to 1990, use on intermediate stature willows averaged 26.2% and use on low stature willows averaged 47.8% 1987-1990 (Fig.1). Shorter stature willows are browsed more heavily than taller willows.

2. Summer utilization rates on low, intermediate and tall stature willows for 1988-1989 are shown in Fig.2. Utilization on all three height categories did not vary greatly. A chi-square test revealed that the differences in utilization rates between the height categories is significant.

3. Our hypothesis is that browse-or ecologically stressed willows are less able to produce secondary compounds such as tannins, and they are therefore subjected to increased browsing. We have collected extensive samples of willows in 1989 and 1990 for analysis of plant defense compounds.

4. The effects of the severe winter of 1988-89 on willow utilization was dramatic. Utilization rates were 3-fold higher than for the previous two winters (Fig. 3). About 24% of the northern elk herd winterkilled and some moose starved to death, so such a dramatic dependence on woody browse was not unexpected.

5. The winter of 1988-89 provided us with another opportunity to test the hypothesis that severely browsed willows are less able to produce secondary defense compounds. Utilization rates on willows remained high during the winter of 1989-90 and summer 1989 rates were higher than summer 1988 rates, in spite of substantially lower ungulate populations. This suggests to us that willows were poorly defended after the tough winter.

6. A widely held belief in the scientific community is that utilization rates of 25-30% can be compensated for, or even stimulate willows, but that utilization rates above that level will result in lowered productivity and eventually death in willows. Few studies in fact have proceeded to the point of eath. However, under this widely-held belief, winter utilization rates on tall willows is acceptable, and use on the intermediate, and short stature willows is excessive.

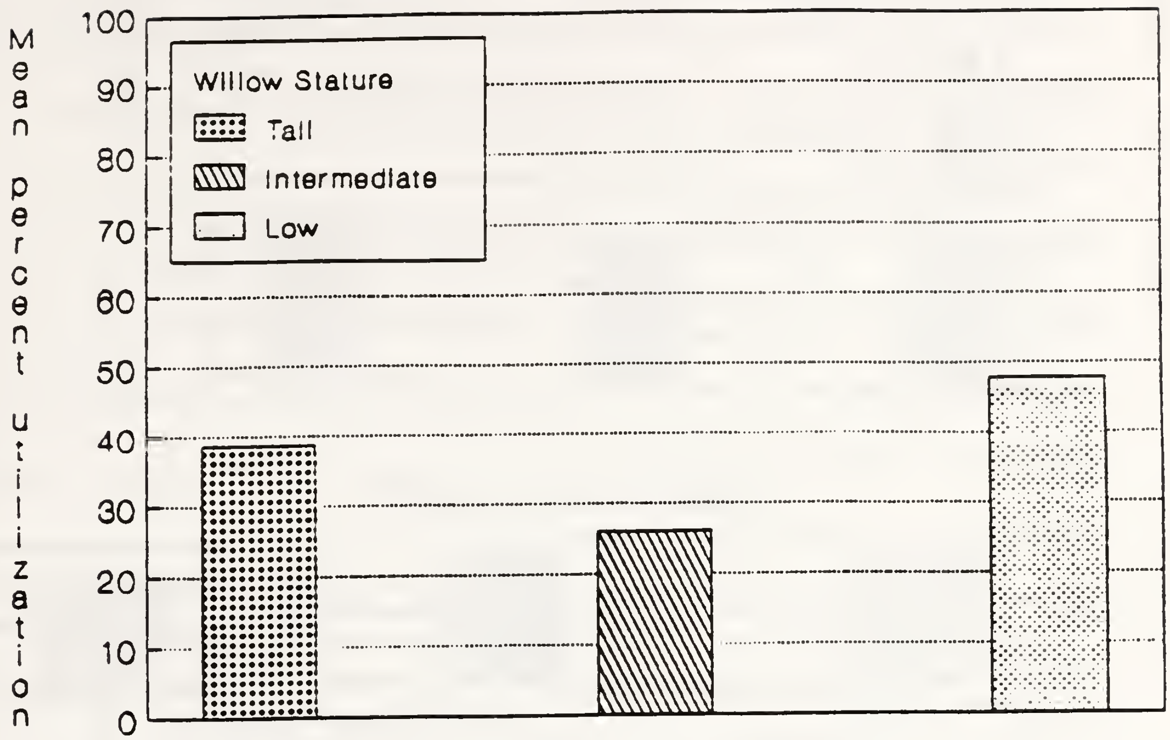


Fig. 1. Average percent winter utilization on tall, intermediate, and low stature willows on Yellowstone's northern winter range, 1987-1990. Low stature willows are more heavily browsed than taller willows.

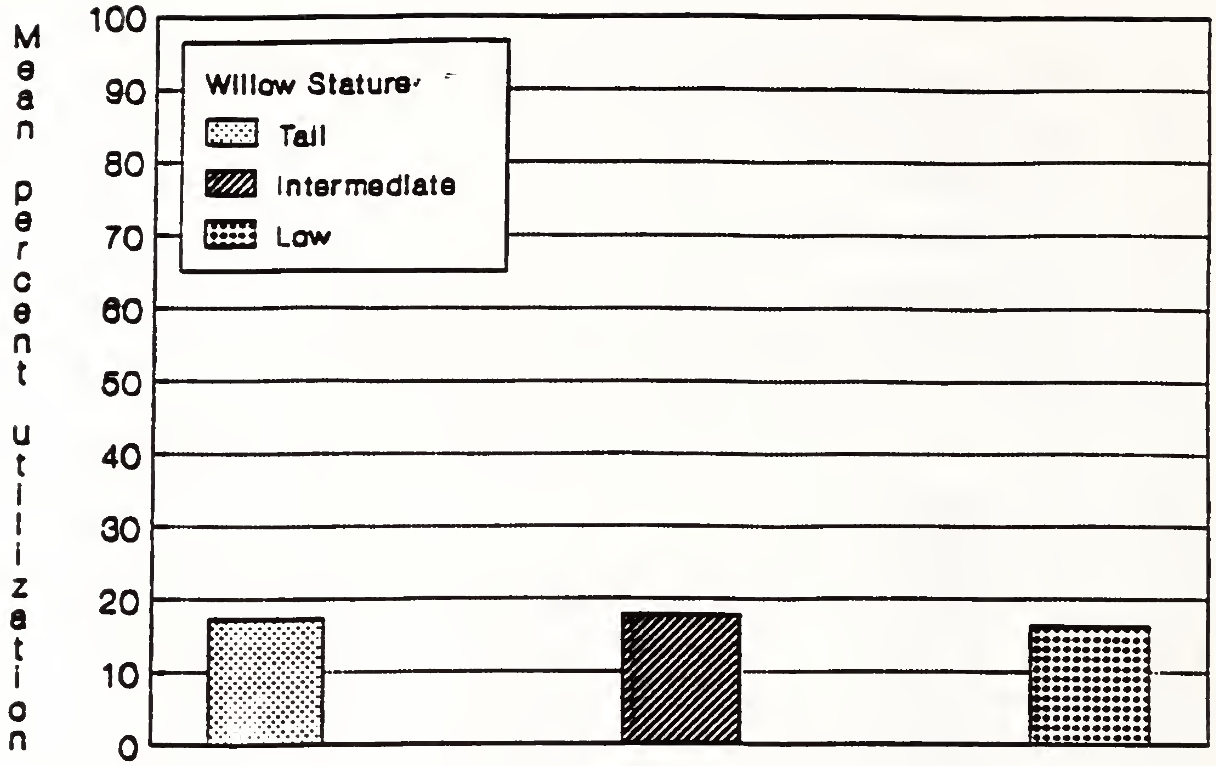


Fig. 2. Average percent summer utilization on tall, intermediate, and low stature willows on Yellowstone's northern winter range, 1988-1989.

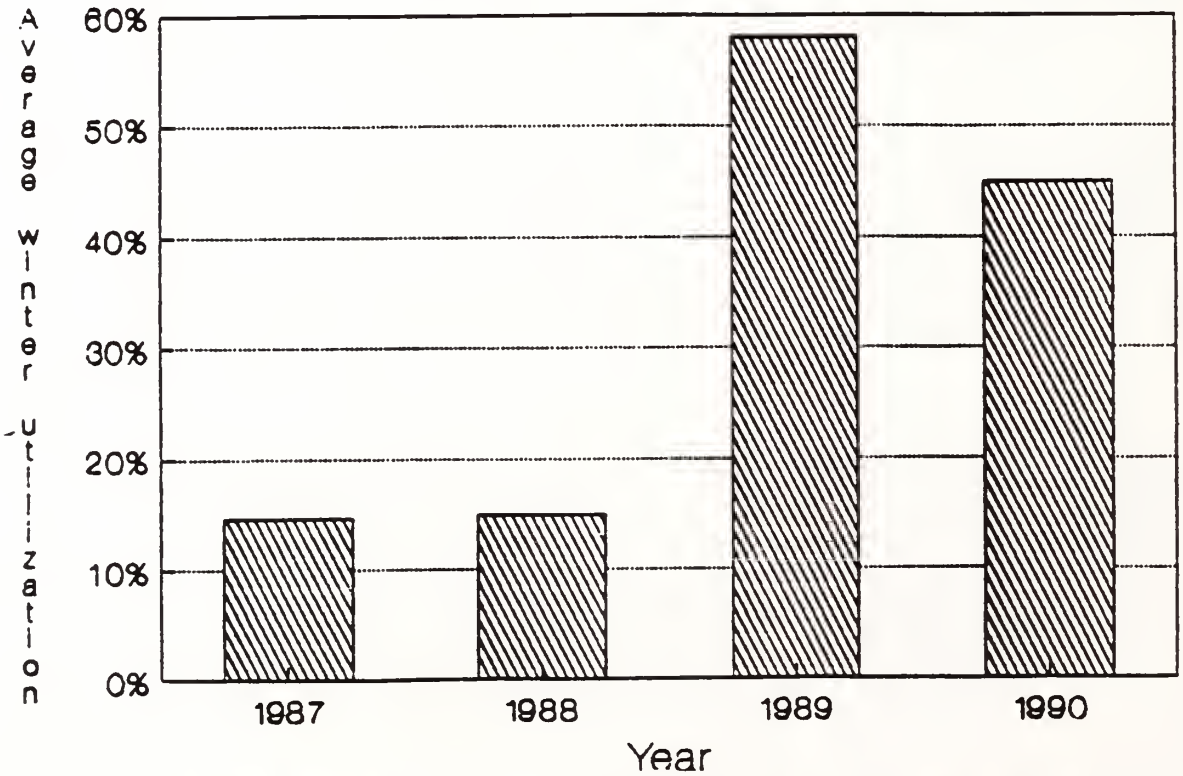


Fig. 3. Average percent winter utilization on willows of the northern range, 1987-1990. Utilization rates for 1987 are based on three areas only.

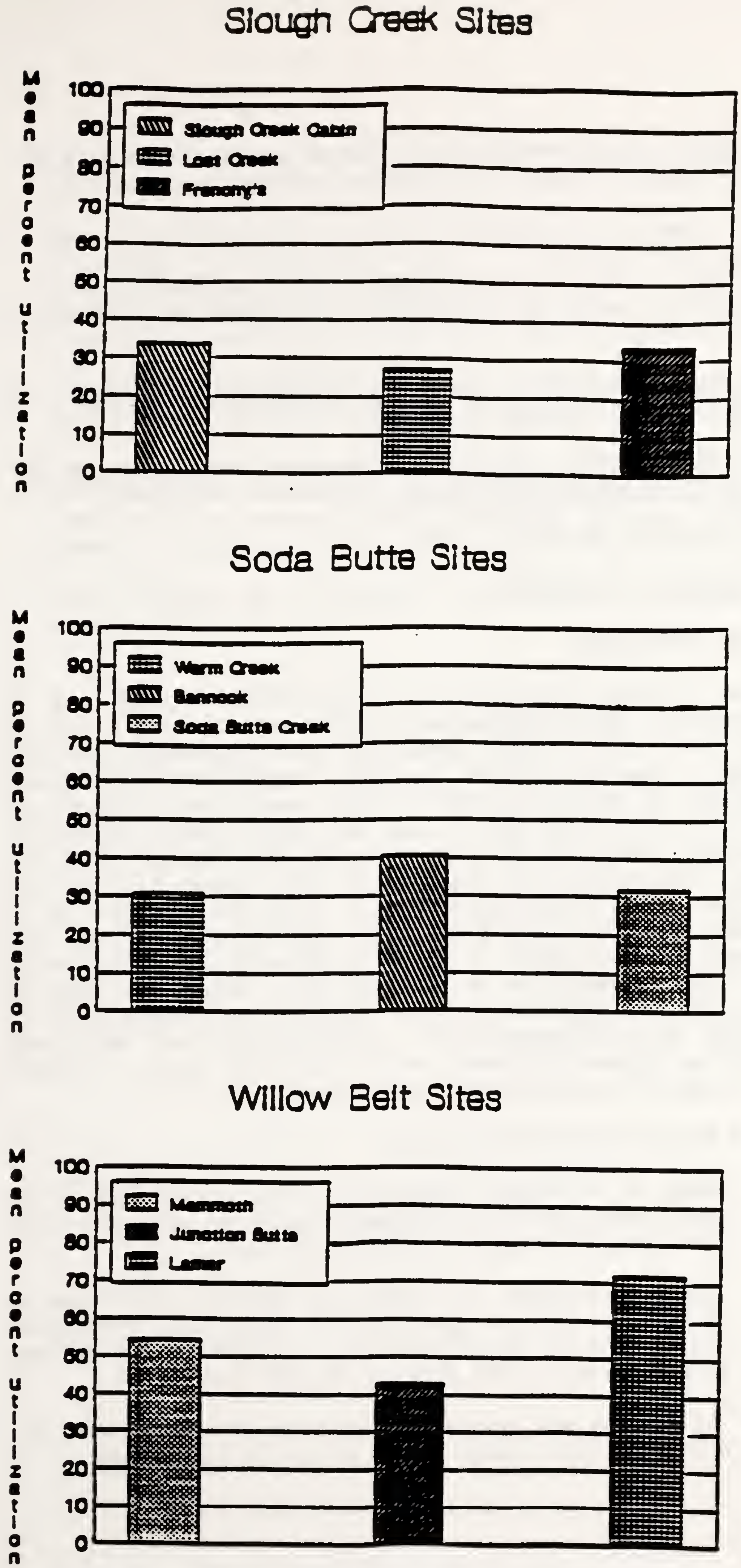


Fig. 4. Average percent winter utilization rates on willows of the Slough Ck. (1988-1990), Soda Butte Ck. (1987-1990), and Willow Belt (1987, 1989-1990) sites on Yellowstone's northern winter range.

TITLE: Tall willow communities on Yellowstone's northern range: A test of the "natural regulation" paradigm.

AUTHORS: Steve W. Chadde and Charles E. Kay

AFFILIATIONS: School of Forestry, University of Montana and Department of Fisheries and Wildlife, Utah State University.

PUBLICATION REPORT STATUS: Accepted, Examining the Greater Yellowstone Ecosystem proceedings.

PROJECTED PUBLICATION: Chapter in a book entitled Examining the Greater Yellowstone Ecosystem, Yale University Press.

PROJECTED PUBLICATION DATE: 1990

DATE OF REPORT: Fall 1989.

SUMMARY OF OBJECTIVES:

Prior to 1968, the National Park Service believed than an unnaturally large population of elk was responsible for the decline in tall willow communities on Yellowstone's northern range. However, under "natural regulation" management adopted in the early 1970's, that agency now believes the decline in tall willows is due to normal plant succession, climatic change, or fire suppression, not ungulate browsing. Thus, the status and trend of willow communities on the northern range since establishment of the park in 1872 can be viewed as a test of the "natural regulation" paradigm. The purpose of this paper is first to document historic changes in willow communities on the northern range and then to evaluate what factor or factors may have been responsible for changes in those communities. Successional trend and status were considered as were soils, available water, climatic variation, fire, and ungulate browsing.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. Based on 44 repeat photographs, tall willow communities have almost entirely disappeared from the northern range since establishment of Yellowstone Park.

2. Willows protected from ungulates exhibit significantly greater growth and canopy-coverage than unprotected plants and in physical stature, resemble the willows which existed in the park during the late 1800's.

3. The decline and current suppression of willows over the entire northern range is due primarily to frequent,

repeated ungulate browsing, and not climatic change, plant succession, or suppression of lightning fires.

4. Ungulate browsing has not only changed the stature and abundance of willow communities on the park's northern range, but also animal communities which are usually associated with those riparian habitats. Entire communities have been affected, not just willows.

5. Ungulate browsing has acted to competitive exclude beaver from nearly all the northern range.

6. The near elimination of beaver may well have had a marked negative feedback effect on the extent of willow communities by lowering water tables and reducing stream flows.

7. These findings do not support the "natural regulation" hypothesis.

TITLE: Aspen regeneration on Yellowstone's northern range following the 1988 fires.

AUTHOR: Charles E. Kay

AFFILIATION: Department of Fisheries and Wildlife, Utah State University.

PUBLICATION REPORT STATUS: None - this is only the first year of a multi-year study.

PROJECT PUBLICATION: (?)

PROJECTED PUBLICATION DATE: 1994(?)

DATE OF REPORT: Preliminary findings were presented at the 1989 and 1990 Yellowstone Research meetings.

SUMMARY OF OBJECTIVES:

Based on 81 repeat photo sets, aspen on the northern range has declined over 95% since Yellowstone Park was created. Park Service biologists attribute this decline to the suppression of naturally occurring lightning fires, not to repeated browsing by an "unnaturally" large elk population. Park Service biologists have postulated that if burned, aspen stands would produce root-sprouted, regenerated stems greater than 2 m tall which, in time, will successfully regenerate those stands. To test this hypothesis, I established 131 photo points containing 773 photo frames in recently burned aspen stands on Yellowstone's northern range. Those sites were photographed in October 1988 and again after the 1989 growing season. In addition to these photo stations, I established several 2 x 30 m permanent belt transects to measure aspen regeneration.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. Despite what was the worst fire season in the park's history, many aspen stands were not overly susceptible to burning. In many cases, fire either swept around the aspen stands, or lightly burned through the stands with little fire-induced mortality of older aspen trees apparent in 1989.

2. Aspen regeneration rates were highly variable one year after the 1988 fires and ranged from 1,000 to over 200,000 stems per ha.

3. In areas without summering elk, fire regenerated aspen suckers averaged 64 cm tall with individual stems approaching 2 m in height. In areas where elk summer on

the winter range, those animals browsed each and every aspen sucker despite an apparent abundance of other forage. In those areas, fire regenerated aspen suckers averaged just over 15 cm in height.

4. I spent 3 days in April 1990 checking many of my aspen burn study plots and found that wintering elk had browsed all those suckers often to within a few cm's of the ground.

5. Measurements in subsequent years will allow me to test the hypothesis that high intensity, infrequent fires which burn a major portion of the winter range are necessary to regenerate aspen stands under the level of ungulate use that presently occurs on the park's northern range. If Yellowstone's burned aspen stands are not able to successfully regenerate, this would falsify the Park Service's "natural regulation" experiment.

6. Experimental aspen burns conducted by the Park Service on the northern range prior to 1988 have failed to produce aspen stems greater than 2 m due to repeated elk browsing.

TITLE: Woody debris movement dynamics in Yellowstone National Park's northern range following the 1988 fires.

AUTHORS: Deron E. Lawrence and G. W. Minshall

AFFILIATIONS: Stream Ecology Center, Idaho State University.

PUBLICATION REPORT STATUS: Submitted to the Proceedings of the 3rd Annual Northern Range Meetings.

PROJECTED PUBLICATION: Summer 1990.

DATE OF REPORT: April 1990.

SUMMARY OF OBJECTIVES:

Woody debris within stream channels is being used to document the effects of the 1988 Yellowstone National Park fires on stream stability. One-hundred meters of stream channel within 22 streams in the Park have had woody debris mapped immediately following the fires, in August of 1989, and in August of 1990. Disturbance was measured by counting the number of pieces of wood lost to or gained within the channel reach of each stream. In addition, wood was tagged in both burned and reference watershed streams (six total) to determine movement patterns.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. More pieces of wood moved in burn streams than in their corresponding reference streams. No data were available for first order reference streams, but it is commonly accepted that these streams are very retentive and stable systems which probably experienced little change (see Figure 1B).

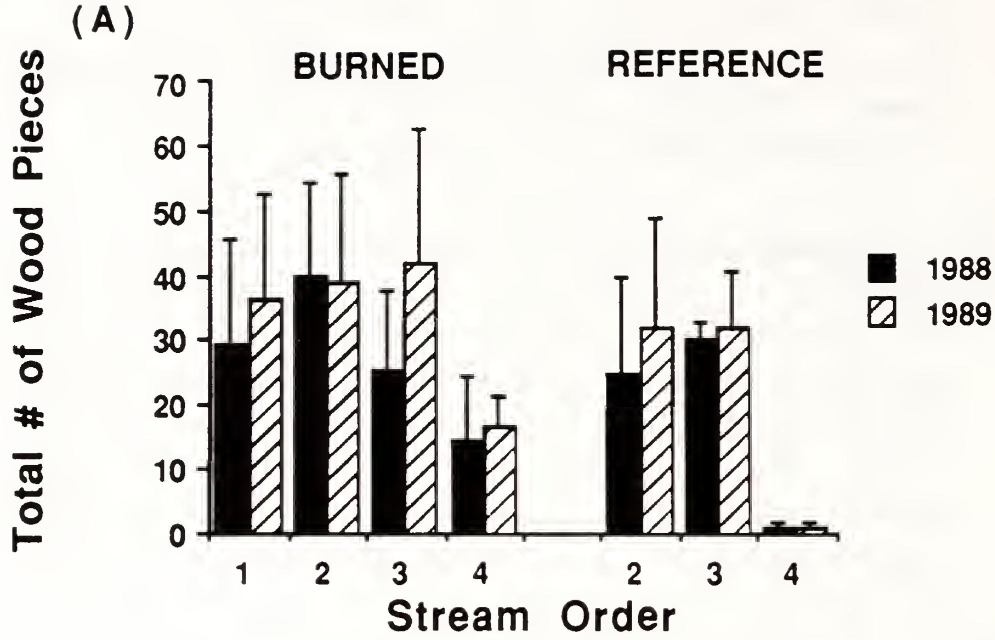
2. Although more wood moved in burn streams, the total number of pieces of wood in a given stream reach remained about the same. This means wood is being exchanged within a reach, but no trend of net gain or loss is occurring. Thus, as the turnover rates decrease to the reference stream values and wood stabilizes within the channel, a similar number of pieces of wood should be present as compared to the pre-fire abundances (see Figure 1A).

3. Wood in the stream channel was tagged in two streams with high spring run-off discharge and two streams with spring base-flow discharge. The maximum distance moved in the former streams was 17.8m, while no wood moved in the stable flow streams. Between 82% and 100% of the tagged wood was found. Reference stream wood was not tagged until 1989, so comparative data is not available yet.

4. In order to determine how far wood moves immediately following its entrance to a stream, wood from the riparian zone was tagged and placed in the streams discussed in (3). Maximum distance moved for high spring flow streams was 83.2m, while stable flow stream wood movement did not exceed 7.5m. The maximum length of a piece moved in peak flow streams was 3.25m (40m movement), while the largest piece of wood moved in the stable flow streams was 2.00m (6m movement).

SPECULATION:

Peak flow discharge is the driving force behind woody debris movement dynamics, and is the direct cause for greater movement in burn streams. Standing crop of woody debris will be determined by the severity of spring run-off or summer storms, and as watershed vegetation biomass increases the peak discharges will decrease. The Yellowstone Park streams were most susceptible to extreme wood rearrangement and channel cutting during spring run-off of 1989, and had the peak flows been more severe then the woody debris in burn streams could have been nearly completely removed. It appears woody debris loading has remained about the same following the fires (woody debris volume still needs to be analyzed), and recovery for the streams to the pre-fire conditions will occur relatively quickly.



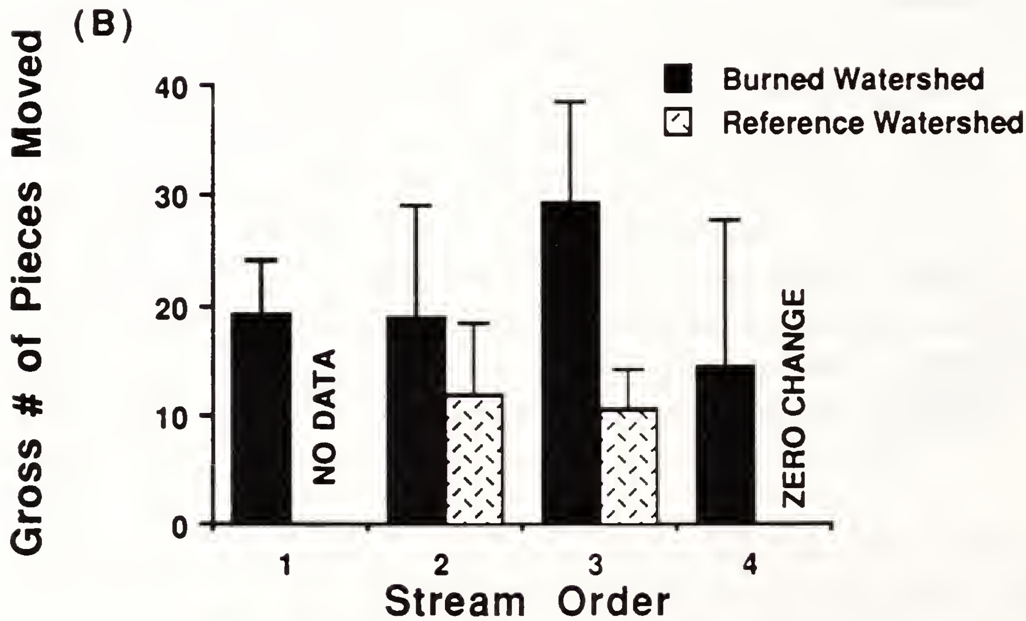


Figure 1. (A) Total number of pieces of wood in 1988 and in 1989 for burned and reference watershed streams of different order. (B) Gross change (total lost added to total gained) in number of pieces of wood in burned and reference watershed streams of stream order 1-4. Error bars represent standard deviations.

TITLE: Interactive ecology of plants, herbivores and climate in Yellowstone's northern range.

AUTHORS: Douglas A. Frank and Samuel J. McNaughton.

AFFILIATION: Syracuse University, Syracuse, New York.

PUBLICATION REPORT STATUS:

1. Aboveground biomass estimation with the canopy intercept method: a plant growth form caveat. Oikos 57, 57-60.
2. Stability increases with diversity in plant communities: empirical evidence. Science (submitted).
3. Dissertation in preparation.

OTHER PROJECTED PUBLICATIONS:

1. Interactive ecology of plants large mammalian herbivores and climate in Yellowstone National Park. Ecol. Monogr.
2. The effect of climate and large herbivores on plant community species composition. Ecology or Vegetatio.
3. The effect of climatic variation on ecosystem function. Am. Nat.
4. The role of ecosystem science in developing Park Service policy. Science.

PROJECTED PUBLICATION DATE FOR WORK IN PREPARATION: 1991.

DATE OF REPORT: June, 1990.

SUMMARY OF OBJECTIVES:

Our major focus was to measure rates of primary production and herbivory, principally in this study by elk and bison, in a variety of plant communities in all seasonal ranges in Yellowstone National Park's northern range. We also estimated the amount of dung deposited in the communities to index the rate of nutrient flow from ungulates to soil microbes. At 4 sites, large permanent exclosures were erected to quantify the effect of large herbivores on primary production in the northern range. We were fortunate to obtain data for 1988 and 1989, 2 very different years in regards to herbivore numbers and climate. This allowed us to examine the impact of these disparate years on ecosystem processes.

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. Primary productivity was stimulated by herbivores. In 3 of the 4 communities, primary production was significantly higher in grazed vegetation in comparison to ungrazed vegetation (Fig. 1). Results were consistent between years for sites there is 1988 and 1989 data. Site s4, which was unaffected by herbivores, was located in the summer range.

We believe the lack of a herbivore response in s4 during both years was due to the 1988 drought, which likely was most severe in the summer range.

2. Primary production and consumption declined from 1988 to 1989. The decline in consumption is not suprising, since there were fewer ungulates in 1989 than in 1988. However, higher primary production in 1988, a drought year, than 1989, a cool and more moist year, is counter-intuitive. The explanation, we believe, involves a combination of drought-induced death of plants that reduced the basal primary production potential of plant communties, and less consumption in 1989 that concomitantly reduced the stimulation of primary production by herbivores throughout much of the northern range.

3. There was a positive linear relationship between herbivore consumption and aPn. This indicates that as primary production increases among patches in the landscape, so will consumption at a constant rate per unit production.

4. The rate of consumption (grams consumed per gram produced) declined in the winter range from 1988 to 1989, while it was unchanged in transitional and summer range sites.

5. There was a linear positive relationship between dung deposited in the sites and consumption. The relationship was indistinguishable between years. This indicates that grazing and nutrient cycling are coupled in the Yellowstone landscape.

6. There was a positive linear relationship between timing of grazing and timing of plant growth. In off-winter range sites, rate of daily production explained 92% and 80% of the variance in daily consumption in 1988 and 1989, respectively. This indicates that during their migration off the northern winter range beginning in spring, ungulates are preferentially grazing in a band of young, nutritious tissue as it progresses through the season from low to high elevations in the park.

7. There was a positive relationship between species diversity and resistance to plant community species composition change during the 1988 drought. These data are the first of their kind that show stability of plant community species composition increases with species diversity.

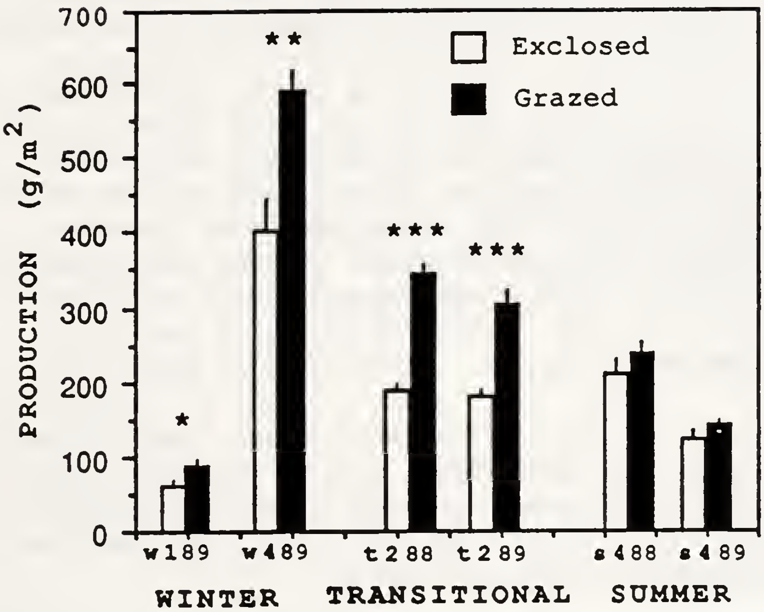


Figure 1. Net aboveground primary production in grazed and ungrazed vegetation in four communities. Sites t2 and s4 were sampled during both 1988 and 1989. • denotes P<.05. •• denotes P<.01. ••• denotes P<.001.

TITLE: Forage species response to grazing

AUTHOR: Linda L. Wallace

AFFILIATION: Department of Botany and Microbiology, University of Oklahoma

PUBLICATION REPORT STATUS: Two manuscripts in preparation

PROJECTED PUBLICATION: Ecology, Oecologia

PROJECTED PUBLICATION DATE: 1991

DATE OF REPORT: May, 1990

SUMMARY OF OBJECTIVES:

1. Determine which forage species were most preferred by bison and elk.
2. Determine how plant community structure is influenced by grazing by both bison and elk.
3. Determine what grazing intensity exists across the northern range.
4. Determine how the most heavily utilized forage species respond to grazing pressures simulated by clipping.
5. Determine whether there are interactive effects of plant competition and grazing on plant growth and survival.
6. Determine what the physiological limits to herbivory are for the most heavily utilized forage species.

SUMMARY OF MOST IMPORTANT RESULTS:

1. At five sites across the northern range that represent winter, summer and transitional range sites, the three most heavily utilized forage species at each site were found to be graminoids. These include both native and introduced (exotic) species. These sites were grazed by both elk and bison.

2. Plant community structure was monitored over a three year period from 1987 through 1989. During the drought year of 1988, species diversity was reduced inside of temporary exclosures. However, the greatest difference in plant community structure was found between years with percent similarity between community measurements at any site averaging 62%. Percent similarity measured between inside and outside exclosures at each site averaged 75%. Therefore, yearly climatic variation will cause a greater change in plant community structure than will the presence of grazing animals.

3. Grazing intensity averaged 75% of the aboveground biomass removed from the preferred forages at the five sites in 1988. Grazing intensity averaged 30% in 1989. These could be attributed to both greater plant growth in the moist summer of 1989 as well as reduced ungulate populations.

4. All of the forage species examined were capable of compensating for tissue lost to herbivory in 1989. Compensation occurs when grazed plants grow at a more rapid rate than ungrazed plants. No

compensation occurred during the drought year of 1988.

5. In the experimental manipulations, plant competition and grazing did significantly interact to influence plant response to herbivory. If a target plant and all its surrounding neighbors were grazed, then the target plant was able to compensate for herbivory. If only the target plant was grazed, then it undercompensated for herbivory; if the target was ungrazed but all its neighbors were grazed, then the target also undercompensated. Therefore, if grazing is selective (such as occurs when only elk graze an area) then plants may undercompensate. However, when grazing is nonselective (such as occurs when bison graze in an area) then plants can compensate for herbivory. Therefore, it appears that bison may be a stabilizing influence in the northern range ecosystem.

6. In a laboratory study where plants were grown in isolation with adequate supplies of water and fertilizer, only one species could be killed by extremely severe levels of clipping. All of the other Yellowstone species possess the ability to tolerate high levels of herbivory.

7. Based upon these results, I feel that the northern range ecosystem is capable of tolerating high levels of herbivory. It is important, however; that both bison and elk are present since if only selective herbivory occurs, plant community structure and system productivity could be altered. I suggest that these data obtained from experimental manipulations be tested by field observations in areas that support only elk.

TITLE: The interaction of fire and grazing on plant productivity and community structure.

AUTHOR: Linda L. Wallace

AFFILIATION: Department of Botany and Microbiology, University of Oklahoma

PUBLICATION REPORT STATUS: Field work still in progress

PROJECTED PUBLICATION: Functional Ecology

PROJECTED PUBLICATION DATE: 1991

DATE OF REPORT: May 1990

SUMMARY OF OBJECTIVES:

1. Determine grazing intensity in burned and unburned grasslands during the two years following the 1988 fires.
2. Determine plant productivity in burned, unburned, grazed and ungrazed grasslands over the above time frame.
3. Determine plant community structure in the above combinations of areas over the same time frame.
4. Determine how plant community structure has changed in permanent transects that were burned by the fires of 1988 at both Junction Butte and Hayden Valley.

SUMMARY OF MOST IMPORTANT RESULTS:

1. Plant community structure was affected variably by the fires. At Blacktail, species richness was greatest at intermediate levels of disturbance with values highest in burned, ungrazed areas and lowest in both unburned, ungrazed areas and burned grazed areas. The site at Mt. Norris exhibited the greatest species richness in unburned areas regardless of the grazing regime. The site at Crystal Creek in the understory of a burned Douglas fir community had the greatest species richness in unburned, ungrazed and burned, grazed areas. Since all sites exhibited such disparate responses, further work will be conducted on these areas to determine what may be responsible for this variance.

2. Species richness was greater after the fire at the Junction Butte site. The transect which did not burn exhibited a reduction in species number while the transect which did burn had many more species present. At Hayden Valley, results were opposite to those at Junction Butte. Species richness was dramatically reduced in the burned transect. This may be due to the area (near Alum Creek) being on thermally influenced soils which are an additional stress to plant growth. Since only a few species are capable of growth on these thermally altered soils, then few opportunists were able to grow in these communities following the fires.

3. Work is continuing on plant samples collected in 1989 and field work will continue in 1990 to determine how grazing intensity and productivity were influenced by the fires.

TITLE: Grassland recovery after burning: a remote sensing approach.

AUTHORS: Evelyn H. Merrill and Ronald W. Marrs

PUBLICATION REPORT STATUS:

1. Annual reports, University of Wyoming- Yellowstone National Park
2. Remote sensing of grassland phytomass. J. Range Management, accepted.
3. Elk dynamics and summer range. Book Chapt. Yellowstone Symposium. in press.

OTHER PROJECTED PUBLICATIONS

International Journal of Fire Management, 1992.

PROJECTED PUBLICATION DATE FOR WORK IN PREPARATION: 1992

DATE OF REPORT: July 1990

SUMMARY OF OBJECTIVES:

(1) Improve pre-fire remote sensing techniques for estimating green phytomass on grasslands sites to monitor vegetation recovery in the initial post fire years and

(2) Determine factors across the landscape that may have influenced the patterns of vegetation recovery.

SUMMARY OF PROGRESS AND FINDINGS:

1. Landsat Thematic mapper (TM) spectral data were acquired for August 2, 1989 for the Yellowstone National Park and mounted on the University of Wyoming remote sensing image processing system.

2. Spectral data were used to derive the 2-D Perpendicular index (PVI) and the 6-D Green vegetation index (GVI) for 40 ground truth sites. These indices are a special class of spectral indices which are linear combinations of n-spectral bands in n-dimensional space. The indices are useful for discrimination of vegetation from soil background.

3. During late July and early August 1989, 40 ground truth plots were sampled for green herbaceous phytomass (Table 1). Ground truth data are being used to calibrate PVI and GVI models.

4. Spectral models built using 1989 data will be tested using Landsat imagery for the same area and additional ground truthing in the summer of 1990.

5. Once GVI/PVI models are validated, we intend to use the models in a GIS system to monitor vegetation recovery and determine landscape factors influencing vegetation recovery.

Table 1. Summary of plots sampled July 27-August 10, 1989.

Plot	Location	Burn[1]	Plot Characteristics Elev	Asp	Slope	CT-DD[1]	Azm
101	Lower Norris	T3	7520	180	15	TFG	135
102	Lower Norris	No	7720	196	25	TFG	322
103	Middle Norris	T1	7800	254	20	TFG	190
104	Middle Norris	T2	7520	328	10	TFG	34
105	Lower Cache	T2	7460	250	10	TFG	280
106	Lower Cache	No	7680	235	5	FN	298
107	Upper Cache	No	8100	230	20	FN	290
108	Upper Cache	No	7940	230	1	TFG	234
109	Upper Cache	T3	8025	283	5	TFG	190
110	Upper Cache	No	7960	195	20	TFG	80
111	Upper Cache	No	7850	184	3	TFG	200
112	Upper Cache	No	7760	295	4	TFG	218
113	Upper Cache	T3	7750	230	10	TFG	322
114	Lamar Flat (52)	T1	6630	0	0	TF	165
115	Lamar Flat (51)	No	7160	206	25	TFG	36
116	Upper Lamar Flat	T4	6710	0	1	TF	65
117	Floating Island (28)	No	6480	0	0	TFG	137
118	Floating Island (29)	T2	6680	0	0	TFG	135
119	Y-L Confluence (30)	T1	6120	80	2	TF	255
120	Y-L Confluence (31)	No	6080	310	4	TF	210
121	Opal Creek	T2	8800	145	5	FNG	50
122	Opal Creek	T2	8740	95	15	FNG	8
123	Opal Creek	T4	8800	95	7	FNG	11
124	Above Opal Camp	No	8960	90	7	FNG	130
125	Above Opal Camp	No	8880	190	15	FNG	120
126	Above Opal Camp	T3	8760	356	3	FNG	170
127	Opal Creek	T4	8800	15	1	FNG	15
128	Opal Creek	No	8660	305	6	FNG	32
129	Specimen Ridge Trail	T2	8770	90	5	TFG	8
130	Mirror Plateau	No	9120	192	20	FNG	272
131	Mirror Plateau	No	9170	0	2	FNG	23
132	Top Specimen Ridge Tr	No	8840	150	20	FNG	76
133	Above Norris Hot Sp	T2	6980	233	5	TFG	138
134	Lower Norris	T1	7250	230	12	TFG	148
135	Lower Norris Rdge Top	No	7800	218	1	FA	136
136	West Of Norris Cliff	T2	7440	180	15	FA	238
137	Upper Norris	No	8130	121	5	TFG	196
138	Pk Midway To Norris	No	8250	171	10	FNG	247
139	Top/Draw Mid-Norris	No	7880	338	10	TFG	326
140	Norris/Next To Cliff	No	7760	302	5	TFG	220

[1]Burn descriptions:

T1= hot fire, all shrubs & litter burned, ground fire complete.

T2= all shrubs killed but some aboveground woody material not consumed, ground fire mostly complete.

T3= some shrubs survived or at least some leaves present, ground fire >50% complete.

T4=light burn, > 50% ground vegetation survived.

[2]Vegetation types follow D. Despain cover map.

TITLE: Report on 1989 suspended sediment and turbidity in the Yellowstone River and selected tributaries from Yellowstone Lake, Yellowstone National Park, Wy., to Tom Miner Basin, Park County, Montana following the 1988 wildfires.

AUTHORS: Roy Ewing and Jana Mohrman

AFFILIATIONS: National Park Service, Yellowstone National Park

PUBLICATION REPORT STATUS: Preliminary Report finished April 1990, final report in late 1990.

PROJECTED PUBLICATION: U.S.Fish & Wildlife Technical Report, Aquatic Ecology Studies, Yellowstone Fisheries Assistance Office.

PROJECTED PUBLICATION DATE: Late 1990 for final report.

DATE OF THIS SUMMARY: May 1990

SUMMARY OF OBJECTIVES: The objectives of the post-fire sediment project were to measure streamflow, suspended sediment, and turbidity in the Yellowstone River and selected tributaries in northern Yellowstone Park that had been monitored for these characteristics in 1985, 1986, and 1987. 1989 measurements will be compared to the pre-fire data.

SUMMARY OF SIGNIFICANT FINDINGS:
<u>CLIMATE</u>, <u>PRECIPITATION</u>, <u>AND</u> <u>STREAMFLOW</u>:

1. The area in and around northern Yellowstone Park received more October-June precipitation in 1989 than in the pre-fire years 1985-1987.

2. Despite greater October-June precipitation, 1989 snowmelt period saw less runoff in the Yellowstone River (Corwin Springs) than in 1986 due to the gradual, cool nature of the 1989 snowmelt season.

3. 1989 summer precipitation in the area was less than in the pre-fire years. 1989 summer streamflow in the Yellowstone (Corwin Springs) was less than in 1986 but greater than 1985's. The greater 1989 summer streamflow in the Yellowstone for less summer precipitation (than in 1985) was probably a lag effect of the thick snowpack and gradual snowmelt since unburned streams in the area also experienced the same precipitation-streamflow relations.

4. Streams in the Yellowstone Park area had two high-flow periods during snowmelt, May 10-11 and June 16-17. The Yellowstone River at Corwin Springs, receiving streamflow from severely to lightly burned drainages, had peak mean daily flow on June 16. With one exception, date of peak flow

seemed to relate to basin elevation, lower basins peaking in May and higher basins peaking in June. The Lamar River, a high basin with large burned areas, peaked in May. This could be a fire effect.

5. Streamflow for all seasons in 1989 in the Lamar River (Tower Junction) was about equal to 1986 values. Since 1986 streamflow was greater than 1989's on the Yellowstone (Corwin Springs) and for most monitored tributaries, this could be a fire effect.

SUSPENDED SEDIMENT AND TURBIDITY.

1. Suspended sediment and turbidity in the Yellowstone (Corwin Springs) and several of the monitored tributaries followed the trend of average streamflow, with 1989 values exceeding those of 1985 but less than the 1986 averages, for all seasons.

2. Fire effects on streamflow, suspended sediment, and turbidity during snowmelt season were minimized by the cool, gradual 1989 snowmelt. The lower snowmelt values caused overall averages to also lower.

3. Post-fire suspended sediment and turbidity were greater than pre-fire values in the Lamar River only for the summer season. Other monitored, burned tributaries also experienced elevated post-fire summer sediment and/or turbidity.

4. Post-fire increases in turbidity were most noticeable in previously non-turbid streams, such as Slough and Lava Creeks.

5. Summer fire effects on stream suspended sediment and turbidity were probably mitigated by the dry 1989 summer.

6. The fact that increases in summer sediment in the Lamar River and other monitored tributaries were not reflected in the Yellowstone at Corwin Springs suggests that sediment from storm runoff may be stored in stream channels upstream from Corwin Springs and may be moved through the stream system during the 1990 snowmelt.

7. Post-fire sediment rating curves for the Yellowstone River at Corwin Springs, the Lamar River at Tower, and several other monitored tributaries show a general decline in slope of the best-fit curves indicating either an increase in low-discharge sediment or a decrease in high-discharge sediment following the 1988 fires. This may have been caused by the mild, low streamflow 1989 snowmelt season.

Fig. 1. SEASONAL AVERAGES OF MEAN DAILY DISCHARGE, CONCENTRATION, SEDIMENT DISCHARGE AND TURBIDITY IN THE YELLOWSTONE RIVER-CORWIN SPRINGS, 1989-1985

	STREAMFLOW (CFS)							CONCENTRATION (MG/L)						
	1986		1989		1985		1987	1986		1989		1985		1987
SNOWMELT	10949	>	9000	>	7821	>	5072	219	>	171	>	90	>	44
SUMMER	4348	>	3158	>	2737	>	2009	30	>	22	>	14	<	18
ENTIRE	6980	>	5487	>	4595	>	3230	106	>	81	>	42	>	28

	SUSPENDED SEDIMENT DISCHARGE (TONS/DAY)							TURBIDITY (NTU)						
	1986		1989		1985		1987	1986		1989		1985		1987
SNOWMELT	8979	>	4718	>	2287	>	672	22	>	14	>	10	>	8
SUMMER	532	>	243	>	113	<	129	11	>	6	=	6	<	8
ENTIRE	3901	>	2027	>	908	>	345	17	>	9	>	7	<	8

TITLE: Effects of Charcoal on Postfire Nitrogen Dynamics in Streams.

AUTHOR: James W. Check

AFFILIATIONS: Department of Biological Sciences, Idaho State University

PUBLICATION REPORT STATUS: Project just initiated, no publishable findings to date.

SUMMARY OF OBJECTIVES:

The objectives of this study are to determine if charcoal affects nitrogen dynamics in streams, and which processes are involved. It was hypothesized that charcoal could: 1) remove nitrogen from the water column by adsorption, and 2) store nitrogen in sediment-buried charcoal and release it later in time, or 3) concentrate nitrogen on the charcoal substrate for microbial processes (nitrification and denitrification).

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. Charcoal was found to comprise up to 40% of the benthic organic matter of streams sampled in August 1989. At reference sites not burned by the fires of 1988 streams sampled had up to 15% charcoal in benthic organic matter.

TITLE: Characterization and comparison of soils inside and outside of grazing exclosures on Yellowstone National Park's northern winter range.

AUTHORS: John R. Lane and Cliff Montagne

AFFILIATION: Montana State University, Bozeman, MT 59715

PUBLICATION REPORT STATUS: Thesis in review

PROJECTED JOURNAL PUBLICATION: Journal of Range Management

PROJECTED PUBLICATION DATE: Spring 1990

SUMMARY OF MOST SIGNIFICANT FINDINGS:

1. The effects of winter grazing by elk on soil chemical and physical properties in Yellowstone National Park's northern winter range were examined inside and outside of eight grazing exclosures. Soil nutrients in the 0-15 cm, 15-30 cm and 30-45 cm depths, soil surface bulk density and double ring infiltration were studied and soil profiles were described for two exclosures each at Gardiner, Blacktail and Lamar Valley and one exclosure each at Mammoth and Junction Butte. A rainfall simulator study comparing sediment yield and surface runoff inside and outside was conducted at two exclosures each at Gardiner and Blacktail and one exclosure at Lamar Valley.

2. Soil profiles were generally similar inside and out, though there were differences. Percent clay in the surface horizon differed by more than (+/-) 5% at Gardiner west, Blacktail east, and Lamar Valley east. Soil texture in the surface horizon was different at both Gardiner exclosures, Blacktail east, Lamar Valley west, Mammoth and Junction Butte.

3. There was no apparent trend in soil nutrient differences inside and outside the exclosures. NO_3-N and NH_4-N for all depths were consistently higher outside at Junction Butte. Blacktail east and Lamar Valley east had consistently higher amounts inside the exclosure. However, not all differences were significant. Soil organic matter was consistently higher at all depths outside of three exclosures; Gardiner west, Blacktail west, and Junction Butte. Differences at Blacktail west were significant ($P=0.10$) for all depths. Other soil nutrients: phosphorus, sulfur, calcium, sodium, magnesium, potassium, zinc, copper, manganese, and iron had no trends. Some exclosures had higher amounts of a nutrient inside for a particular depth while others had higher amounts outside. Some differences were significant others were not.

4. All exclosures but Blacktail east trended toward higher soil surface bulk density outside the exclosure compared to inside. At Gardiner east, Lamar Valley east, Mammoth, and Junction Butte the differences were significant at the 90% confidence level.

5. All exclosures except Blacktail east and Gardiner west had higher double ring infiltration rates inside. None were significantly different. Double ring infiltration rates mostly followed the pattern of higher infiltration associated with lower surface bulk density inside the exclosures.

6. A triple replication rainfall simulator study was conducted to measure the effects of three treatments on runoff and sediment yield inside and outside of five exclosures. The treatments were: 1) vegetation undisturbed, 2) vegetation clipped and left on the surface, and 3) clipped vegetation and litter removed from the soil surface. Surface runoff and sediment yield were higher outside the exclosure for all three treatments. The differences were not significant ($P=0.10$) for treatment 1, vegetation undisturbed. For treatment 2, vegetation clipped and left on the surface, Gardiner east, Blacktail east and Lamar Valley east had significantly higher surface runoff outside the exclosures; none of the differences in sediment yield were significant. When the clipped vegetation and litter were removed, treatment 3, surface runoff at Blacktail east and west and sediment yield at Blacktail east and Gardiner west were significantly higher outside.

7. These results display some statistically significant differences as well as nonsignificant trends. Further replicates may or may not demonstrate statistical significance of these trends. Because soils data were not collected prior to exclosure establishment, it is difficult to ascertain if significant differences inside and outside of exclosures are due to no grazing inside, increased intensive grazing outside, or more likely a combination of both.

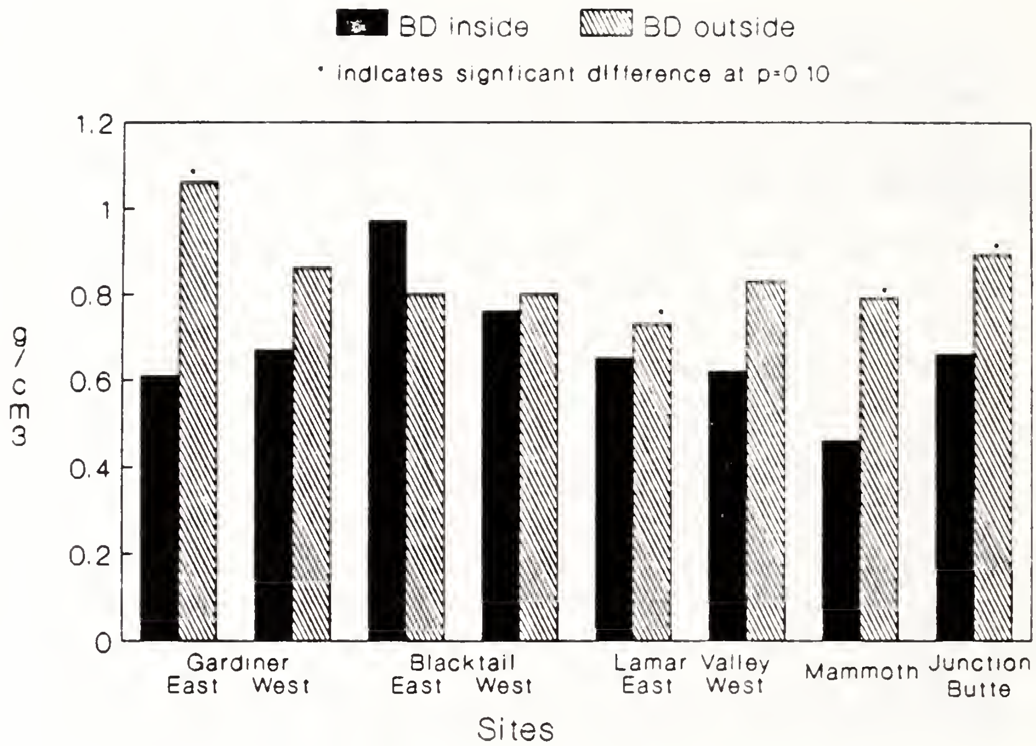


Figure 1. Soil surface bulk density of soils inside and outside of eight exclosures.